Appendix AC

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NESTING ECOLOGY AND HABITAT OF THE NORTHERN GOSHAWK IN UNDISTURBED AND TIMBER HARVEST AREAS ON THE TARGHEE NATIONAL FOREST, GREATER YELLOWSTONE ECOSYSTEM

by

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A thesis

submitted in partial fulfillment

of the requirements for the degree of

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ABSTRACT

I investigated nesting ecology and habitat of a previously unstudied population of Northern Goshawks (*Accipiter gentilis*) on the Targhee National Forest in eastern Idaho and western Wyoming from 1989 to 1995. Twenty seven current and 4 historical territories in Douglas fir and lodgepole pine habitat were monitored. My main objectives were to describe nesting habitat at 5 hierarchical spatial scales, to determine the relationship between productivity/occupancy and habitat features, and to evaluate the effects of timber harvesting. Habitat analysis areas included: the nest tree, nest plot (0.13 ha), nest area (NA: 81 ha), post-fledgling family area (PFA: 162 ha), and the forging area (FA: 2428 ha). I determined habitat selection at the nest site level by comparing nest plots to random plots at 26 territories. Analysis of habitat within the home range area (NA, PFA, FA), was accomplished using ARC/INFO GIS vegetation coverages.

Goshawk territories produced an average of 1.96 young per nest; occupancy rate averaged 61%. Annual productivity was negatively correlated with early spring precipitation, and positively with temperature. Goshawk territories contained 1 to 7 alternate nest trees located in areas of extensive mature forest habitat: mature forest cover averaged over 60% in the NA, PFA and FA. Few territories had less than 50% mature forest cover at any analysis area. Goshawks selected nest sites on north and west aspects that had taller trees, greater basal area, greater under canopy space, and higher density of trees in the 38-46 cm diameter size class compared to random sites. Productivity was positively related to basal area at the nest site, and both productivity and occupancy were positively related to the proportion of sagebrush/shrub cover within the FA, indicting its value as foraging habitat. High occupancy territories (>50% occupancy) had significantly more mature forest cover within the NA and PFA, and less seedling and young forest cover.

At 10 territories monitored pre- and post-harvest, timber harvesting significantly reduced the amount of mature forest within the home range area with greatest reduction within the NA (33%). Average occupancy rate decreased in the post-harvest period from 79% to 47% at these territories but this difference was not significant. Occupancy at 15 post-harvest territories was positively related to the amount of mature forest cover retained within the NA. Large decreases in mature forest cover at three historical territories in salvage logging areas indicate the need for modification of current silvicultural practices to maintain goshawk nesting habitat over time in timber management areas.

Unplanned, large-scale experiments are in progress in forested landscapes, as logging reduces the amount of remaining habitat. By taking advantage of these uncontrolled experiments, we may learn something about the effects of habitat loss on spotted owls. (p. 145) [or goshawks, author's note]

A Conservation Strategy for the Northern Spotted Owl
(Thomas et al. 1990)

INTRODUCTION

Reductions in a number of raptor populations throughout the world have been attributed to habitat destruction by man and associated loss of food supply and nest sites (Newton 1991). In the western United States in the early 1970's, public concern developed over the effects of timber harvesting on wildlife species, including raptors, in late-successional forests (Ruggiero et al. 1994). Although attention and research focused mainly on the Northern Spotted Owl (*Strix occidentalis caurina*) in the Pacific Northwest (Thomas et al. 1990, Raphael et al. 1996), studies on the Northern Goshawk (*Accipiter gentilis*) were also initiated during the 1970's (Bartelt 1974, Reynolds 1975, Hennessy 1978, Reynolds and Wight 1978, Reynolds 1979). Both raptor species, due to their association with mature forest habitat and narrow ecological tolerances, were thought to be vulnerable to timber harvesting which replaces older age classes of forest habitat with younger seral stages (McCarthy et al. 1989). Over the past twenty-five years, the Northern Spotted Owl, which was listed as a threatened species in 1990 under the federal Endangered Species Act, has become one of the most intensively studied birds in the world (Gutiérrez 1996), but data on Northern Goshawk populations are lacking for many areas of the western United States.

Successful conservation management of wildlife species depends upon our understanding the resources needed by a species to persist over time (Morrison et al. 1992, Manly et al. 1993, Ruggiero et al. 1994). Habitat requirements often vary over the geographic range of a species, so conclusions from habitat studies from one location may be misleading if applied to other locations, especially if ecological conditions are dissimilar (Ruggiero et al. 1994). The purpose of this study was to document the nesting ecology and habitat of the Northern Goshawk on the Targhee National Forest in eastern Idaho/southwestern Wyoming, where it was previously unstudied. The study was designed to gain an understanding of local habitat requirements during the breeding season, prey use, and patterns of occupancy and productivity. I also wanted to determine how timber harvesting was changing habitat within estimated home range areas, and whether habitat changes resulting from harvesting were affecting productivity and occupancy. Since the scale at which habitat data are collected can greatly influence our understanding of habitat requirements, especially for a large-ranging species such as the goshawk (Wiens 1981, Orians and Wittenberger 1991, Block and Brennan 1993, Keane and Morrison 1994), I analyzed habitat within estimated home range areas at five different scales using known nest sites as the focal point.

BACKGROUND

Goshawks, in common with other species in the genus *Accipiter,* exhibit adaptations thought to be advantageous for life in forest habitats. With relatively wide, short wings and a long tail, goshawks can maneuver through woodlands in pursuit of prey, relying on agility and strength to make kills while avoiding injury to themselves (Beebe 1974; Jones 1979; Snyder and Snyder 1991). Although the goshawk is considered to have a circumpolar distribution and be conspecific with the goshawk in Europe and Asia, morphological, behavioral, and plumage differences exist between the North American and Eurasian forms (Wattel 1973).

Three subspecies of the goshawk have been described in North America: *A. g. atricapillus,* the most widespread subspecies and the subject of this study; *A. g. laingi*, found on the Queen Charlotte Islands and in southeast Alaska; and *A g. apache* in southern Arizona and Mexico (Johnsgard 1990). The breeding range of the goshawk in North America extends from west central Alaska throughout the boreal forests of Canada, southward into forested and montane habitats in the western and eastern United States (Johnsgard 1990). In the eastern United States, it nests in deciduous, mixed and coniferous forests. It does not breed in most of the central and southern portions of the United States (Johnsgard 1990). Its farthest breeding extension southward is in the Rocky Mountain cordillera in northern Mexico (Johnsgard 1990). In the western, contiguous United States, goshawks are generally associated with mature and old growth coniferous forest habitat during the breeding season, although average tree size and stand structure of nesting habitat vary among regions and forest cover types (Reynolds 1989, Marshall 1992). Most nest sites occur in conifer, and mixed conifer and aspen (*Populus tremuloides*) forests.

Goshawks also nest in pure aspen stands in high elevation shrubsteppe habitat in Nevada, Utah and Colorado (White et al. 1965, Herron et al. 1985, Younk and Bechard 1994).

Due to concern over potential effects of timber harvesting on nesting habitat, the U.S. Forest Service (USFS) in 1986 designated the goshawk a national indicator species for mature forest habitat under the Resources Planning Act Program (Sidle and Suring 1986). Subsequently, a number of individual National Forests identified the goshawk as a Management Indicator Species (MIS) in their ten year Land Management Plans. In addition, the goshawk has been classified as a Sensitive Species by the Southwestern (1982), Pacific (1982), and Intermountain West Regions (1991) of the USDA Forest Service (Reynolds et al. 1992, Block et al. 1994). Public concern over management of this species continues to grow. At least three petitions to list the goshawk as an Endangered Species have been filed for consideration by the U. S. Fish and Wildlife Service over the past five years (Block, Morrison, and Reiser 1994; Ornithological Newsletter, April 1996). Although only one published study has presented evidence for a regional population decline in this species (Crocker-Bedford 1990), the lack of population data overall and absence of regulatory mechanisms to protect nesting habitat in many areas, indicate that some concern is warranted over population trends.

As with early spotted owl management in the western United States (Thomas et al. 1990), initial management guidelines for the goshawk called for protecting only small buffers (8-20 ha) surrounding known nest sites (Reynolds 1989). A study on goshawk reproduction in northern Arizona on the Kaibab National Forest raised questions about the efficacy of such buffers in protecting sufficient nesting habitat (Crocker-Bedford 1990). New management recommendations developed in 1991 for the goshawk in the southwestern United States recognized the need to manage large 6000 acre (2428 ha) home range areas which included all goshawk activities during the breeding season, not just those associated with the nest site (Reynolds et al. 1992). These recommendations are being used by National Forests in other USDA Forest Service Regions of the western United States to develop management guidelines for protecting goshawk habitat, including the region where this present study was located (USDA FS Region Four, Intermountain Region) (Gray Reynolds, Regional Forester, Letter to Forest Supervisors, Oct. 13, 1992).

Although goshawk nesting habitat has been studied at a number of locations in the contiguous western states including South Dakota (Bartelt 1974), Utah (Hennessy 1978, Fischer 1986, Johansson et al. 1994), Oregon (Reynolds 1979, Moore and Henny 1983, Bull and Hohmann 1994), Colorado (Shuster 1980, Joy et. al. 1994), California (Saunders 1982, Hall 1984, Austin 1993, Hargis et al. 1994,), Arizona (Crocker-Bedford and Chaney 1988), New Mexico (Kennedy 1988, Siders and Kennedy 1996), Idaho (Hayward and Escano 1989), Nevada (Younk and Bechard 1994), and Wyoming (Squires and Ruggiero 1996), few of these studies analyzed entire home range areas. Most habitat analyses focused only on nest trees and a small activity area or stand surrounding them. Of the other studies, Bartelt (1974) and Hall (1984) analyzed vegetation cover within a few estimated home range areas, and Johannson (1994) analyzed post-fledgling family areas (243 ha) surrounding known nest sites. Radio tracking studies by Fischer (1986), Kennedy (1988), Austin (1993), and Hargis et al. (1994) detailed actual use areas by breeding adults.

The Targhee National Forest (TNF), located within the Greater Yellowstone Ecosystem in eastern Idaho and western Wyoming (Fig. 1), is an administrative unit of the USFS Intermountain Region (Region Four). Prior to the 1980's, no permanent records were maintained on goshawk breeding sites on the TNF. Wildlife guidelines written in 1979 called for managing a four hectare buffer surrounding *Accipiter* nests and maintaining "a forested environment adjacent to at least a portion of the buffer areas" within management areas (USDA FS 1979). District biologists in the early 1980's began to document the location of active nest sites found within timber management areas. Since 1985, uncut buffers of varying sizes (0.2 ha-121 ha) were maintained around some nest sites found within sales units (District Records, Targhee National Forest, 1981-1988).

The TNF initiated a goshawk monitoring project in 1989 to determine the status of historical goshawk territories and to describe nesting habitat (Patla 1990; Patla 1991; Patla and Trost 1995). The present study developed out of this initial monitoring program. I have used habitat data for this analysis collected from 1989 through 1993, and nest monitoring data collected from 1989 through 1995.

OBJECTIVES

Even though concern about the effects of timber harvesting on nesting habitat stimulated research initially on the goshawk, and many habitat studies have been located within forest areas managed for timber production, the studies themselves have provided little information on the proportions of cover types found within home range areas, or described the history and scale of disturbances affecting nesting habitat. Consequently, my study focuses on nesting habitat over large areas, and the effects of timber harvesting on both habitat and goshawk reproductive success.

The primary objective of my study was to describe goshawk nesting ecology including nesting habitat at five hierarchical spatial scales at territories occupied at least once between 1989 and 1993 (n=27). Habitat analysis areas included:

1) the nest tree
2) nest plot (0.13 ha circular plot surrounding nest trees)
3) nest area (NA: 81 ha circular area surrounding and including all nest sites)
4) post-fledgling family area (PFA: 162 ha circular area surrounding nest area)
5) the foraging area (FA: 2428 ha circular area centered at nest sites).

The terms and sizes for the larger spatial components analyzed (NA, PFA, and FA) were based on definitions used in *Management Recommendations for the Northern Goshawk in the Southwestern United States* (Reynolds et al. 1992) with some minor modifications to facilitate analysis. This document recommended managing an estimated home range area of 6000 acres (2428 ha) based on goshawks studies both in Europe and North America. This home range area was divided into three spatial components based on goshawk activity during the nesting season: nest area (180 acres or 73 ha), a post-fledgling family area (420 acres or 170 ha), and a foraging area (5400 acres or 2185 ha). I used ARC/INFO GIS (Geographic Information System) vegetation coverages supplied by the TNF to analyze cover types found within the home range area. As part of my habitat analysis, I determined habitat selection at the nest site level by comparing habitat plots at nest sites to random plots in 26 territories.

My second objective was to determine the relation of habitat features at different spatial scales to goshawk productivity and occupancy. I used stepwise linear regression to: 1) analyze the relationship between habitat features at individual nest sites and number of young produced per nest, and 2) analyze the relationship of cover types within estimated home range areas to occupancy and productivity of territories that had been surveyed a minimum of three years (n=22). In addition, I compared proportions of mature forest cover within home range areas of high and low occupancy territories.

My third and final objective was to evaluate of the effects of timber harvesting. I used three approaches. First, I analyzed loss of mature forest habitat at current nesting territories (n=10) where goshawks nested prior to harvesting, and compared productivity and occupancy pre- and post-harvest. This was to determine the extent of habitat change resulting from timber sales in the vicinity of goshawk nests, and to determine if habitat changes were related to reproductive success. Second, I compared the proportion of mature forest cover in post-harvest high and low occupancy territories to determine if the amount of mature forest habitat remaining in disturbed territories was related to how often these territories were reoccupied by goshawks. Third, I measured the loss of mature forest habitat at three historical nesting territories in salvage harvest areas where goshawks had nested previously but were not found during the current period. From this analysis I hoped to gain some insight into the extent of habitat alteration that was occurring over time in heavily logged areas of the TNF and possible threshold effects.

STUDY AREA

The TNF comprises the western portion of the Greater Yellowstone Ecosystem. Yellowstone and Grand Teton National Parks, and the Bridger Teton National Forest form its eastern boundary (Fig. 1). The TNF contains approximately 728,000 ha located in southeastern Idaho (84%) and western Wyoming (16%) (USDA FS 1985). The TNF is bordered to the north by the Continental Divide which runs along the crest of the Centennial Mountains on the Idaho/Montana border (Fig. 2). The Big Hole and Snake River Ranges, and the Snake River comprise the southern and southwestern boundaries. In its farthest extension westward, the TNF includes portions of the Beaverhead Mountains and the Lemhi Range (Fig. 2).

Topography

The TNF falls within two physiographic provinces and contains a diversity of topography and geological substrates. The majority of the TNF falls within the Middle Rocky Mountain Province, an area of high, thrust faulted mountains which includes portions of the Teton, Big Hole, Snake River and Caribou Mountain Ranges, and the Island Park Geothermal Area (IPGA) (Steele et al. 1983, Whitehead 1983). The IPGA is not mountainous but is an extensive volcanic plateau formed by lava and ash flows (Markow 1994). The Centennial Mountain Range in the northern portion of the TNF is considered part of the Northern Rocky Mountain Province; it contains a complex assortment of folded and faulted sedimentary formations (Steele et al. 1983).

The study area consists of steep mountainous terrain and plateau bisected by many streams which drain into the Snake River and its tributaries such as the Henry's Fork and Teton River. Mountain ranges rise out of fairly broad, flat mountain valleys and plateaus. Elevations range from 1585-3470 m.

Climate

Most of the TNF lies within Baker's (1944) Western Wyoming Climatic Region. The climate overall is characterized by long, cold winters with heavy snowfall and mild, dry summers. Because the TNF is extensive and contains a broad elevation range, local precipitation and temperature conditions vary widely (Markow 1994). Total annual precipitation over much of the TNF ranges between 61 and 102 centimeters. Highest precipitation occurs in the higher elevation areas of the IPGA, the Teton Range, and southeastern Snake River Range (Markow 1994). The western Centennials and southern Beaverhead Range are substantially drier compared to the rest of the TNF receiving only 30-41 centimeters of precipitation or less annually (Markow 1994). Thirty year (1951-1980) mean snow depth in April and May, when goshawks begin nesting activity, measured 122 and 56 centimeters respectively at Island Park (elevation 1918 m) in the northern portion of the TNF, and 122 and 66 centimeters at Pine Creek Pass (elevation 2049 m) south of Driggs, ID. Mean monthly temperatures (1951-1980) ranged from a low of -10° C in January to 16° C in July at Island Park. At Driggs, mean temperatures for January and July respectively were -8° and 18° C (National Oceanic and Atmospheric Administration, National Climatic Data Center).

Vegetation

The TNF falls within the northern portion of the Middle Rocky Mountain and the southern portion of the Northern Rocky Mountain vegetation zones as defined by Daubenmire (1943). A more recent classification places it within the Southern Continental Phytogeographic Province within the Northern Rocky Mountains (Habeck 1994). Forest cover within this province is confined in most places to a relatively narrow zone between 2000 and 2700 m above sea level (Habeck 1994). Currently 66% of the total land area of the TNF (500,721 ha) is classified as forested (USDA FS 1996). Forest habitat community types on the TNF have been described by Mueggler and Campbell (1982), Steele et al. (1983), Youngblood et al. (1985), Mueggler (1988) and Markow (1994). Vegetation types tend to occur in overlapping elevational zones with distribution influenced also by aspect and soil type (Steele et al. 1983).

In the subalpine forest zone just below treeline at 2500 to 3500 m elevation, major dominant tree species include subalpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmanii*), whitebark pine (*Pinus albicaulis*) and limber pine (*Pinus flexilis*) (Despain 1990; Habeck 1994).

The montane zone, where all goshawk nest sites have been found to date, ranges in elevation between 1800 and 2500 m (Habeck 1994). The two tree species that predominate within this zone are the primary commercial trees harvested on the TNF: Douglas fir (*Pseudotsuga menziesii* var. *glauca*) and lodgepole pine (*Pinus contorta* var *latifolia*) (Markow 1994). The two species occur both in pure stands or together in mixed conifer stands along with Engelmann spruce, subalpine fir, whitebark pine or limber pine (Despain 1990) . Overall, lodgepole pine and Douglas fir comprise 37% and 25%

respectively of all forested land found on the TNF (USDA FS 1996). Mixed stands of lodgepole pine and Douglas fir account for another 24% (USDA FS 1996).

Douglas fir stands predominate in the Centennial Mountains and in portions of the Snake River and Caribou Ranges. They are found primarily on calcareous and basic extrusive volcanic substrates (Markow 1994). Lodgepole pine and quaking aspen (*Populus tremuloides*) often occur as seral species within Douglas fir stands. Associated shrubs, forbs and grasses include *Acer glabrum, Paxistima myrsinites, Mahonia repens, Symphoricarpos albus, Symphoricarpos oreophilius, Amelanchier alnifolia, Spirea betulifolia, Vaccinium scoparium, Calamagrostis rubescens, Arnica cordifolia, Carex geyeri*, and *Poa nervosa* (Markow 1994).

Extensive stands of lodgepole pine cover the IPGA where it is thought to be a climax species due to a combination of low precipitation, nutrient-poor rhyolitic soils, and fire regimes (Despain 1990, Markow 1994). The understory of lodgepole pine forests is usually sparse and consists of few species. The most common plants associated with lodgepole pine include *Vaccinium scoparium, Sorbus scopulina, Lonicera utahensis, Symphoricarpos spp., Amelanchier utahensis, Calamagrostis rubescens, Poa nervosa; Carex geyeri, Antennaria rosea, Arnica cordifolia, Spiraea betulifolia*, and *Lupinus argenteus* (Markow 1994).

Quaking aspen stands often occur along the lower edge of the montane zone. These are most extensive along the South Fork of the Snake River in the southern portions of the TNF. Due to its wide environmental tolerance, however, aspen is found in scattered stands throughout the TNF at all elevational gradients (Markow 1994, Mueggler and Campbell 1982). It comprises 9% of the total forested area found on the TNF (USDA FS 1996). The understory of aspen stands resembles that of adjacent conifer communities but is usually more species-rich and often more prolific. This is attributed to the more mesic characteristic of such sites and the rapid decomposition of woody material and leaves (Markow 1994, Peet 1988).

Public and private lands adjacent to the TNF consist mainly of sagebrush (*Artemisia tridentata*)-grasslands, agricultural fields, cultivated pasture land, forest land and an increasing number of developed homesites (Glick et al. 1991). Along the river floodplain zones, cottonwood (*Populus*, sp.) can be found (Habeck 1994). Total area of timberland (including all tree species, size classes and ages) located outside of the TNF in adjacent Idaho counties (Teton, Clark, Fremont, Madison, and Bonneville) equals only about 10% of the total area of timberland found on the TNF (Chojnacky 1995). Considering this proportion, it is likely that the majority of the local goshawk breeding population nests on Forest Service land.

Regional History of Fire and other Disturbance Factors

The forests of eastern Idaho and western Wyoming burned at fairly regular intervals prior to the onset of fire suppression in the early 1900's (Habeck 1994; Steele et al. 1983). Despain (1990) has suggested that early fire suppression efforts were probably most effective in sagebrush areas, rather than forests, until the use of aircraft and smoke jumpers increased in the early 1950's. In presettlement times, low intensity fires are thought to have occurred every 20-50 years in Douglas fir forests, and every 40-60 years in lodgepole pine forests (USDA Forest Service 1996, Habeck 1994). Large stand replacement fires in lodgepole pine occur approximately every 100 years and are thought to be tied to mountain pine beetle (*Dendroctonus ponderosae*) infestations in mature stands (USDA Forest Service 1996), although that idea has been challenged by Despain (1990). Cyclical outbreaks of epidemic population levels of mountain pine beetle and Western spruce budworm (*Choristoneura occidentalis*) kill numerous whitebark pine, lodgepole pine and Douglas fir (USDA Forest Service 1996, Habeck 1994). Outbreaks are closely correlated with drought conditions (Habeck 1994). Extensive, unregulated grazing by both cattle and sheep in the early 1900's substantially affected forest communities by depleting forage plants and altering grass-conifer competition. Localized alteration by grazing still occurs in some areas (Steele et al. 1983; Habeck 1994). Logging of forests in the early settlement period was concentrated in accessible areas near towns and mines, where the majority of high quality older trees were removed (Steele et al. 1983). Modern large-scale logging operations expanded throughout the region to the point where examples of undisturbed forest communities at lower elevations are becoming rare except for stands of low quality timber on steep terrain (Steele et al. 1983). Outside of wilderness areas and national parks, where higher elevational communities still exist, examples of old growth-forest are rapidly disappearing (Steele et al 1983, Habeck 1994).

Forest Composition and Timber Management on the TNF

Fifty-seven percent (284,540 ha) of the forested land on the TNF (38% of the total land area) falls within the category of "tentatively suitable forest land" considered capable of producing marketable timber (USDA Forest Service 1996). This is land that is capable of producing crops of industrial wood without irreversible damage to soils or watersheds, can be adequately restocked within five years, and has not been withdrawn for other purposes such as wilderness areas (USDA FS 1996). The floristic composition of the suitable forest land is lodgepole pine (54%), Douglas fir (19%), a mix of these two species (15%), other conifers mixed (6%), spruce/subalpine fir (1%) and aspen (5%). Currently these suitable forest lands consist of 69% mature and 4% pole-sized trees. Approximately 26% of this suitable forest land area has been harvested since 1960 and is classified currently as sapling (6%), seedling (14%) or unstocked areas (6%) (USDA Forest Service 1996).

Prior to 1960, only minor timber harvesting occurred on the TNF. During the early 1960's, a mountain pine beetle infestation began in lodgepole pine. leading to an intensive salvage logging operation which peaked during the late 1970's (USDA FS 1985). The TNF in 1960 sold the largest single timber sale at that time in the continental United States: a sale for 318 million board fee (MMBF) in the Island Park area which was to be harvested over a period of 18 years (USDA FS 1985). Between 1981 and 1990, Douglas fir was harvested in addition to lodgepole pine and mixed conifer stands (Analysis of Management Situation, Targhee National Forest, Nov. 1992).

The most common harvest method used on the TNF was clear-cutting of lodgepole pine and mixed conifer stands. For harvest of Douglas fir, either seed tree or shelterwood methods were used, retaining a variable number of mature trees for a specified period within harvest units after the initial cut. All these methods are considered "even-aged" management systems, that is entire stands were treated (Thompson et al. 1995) . In "uneven-aged" systems, only single trees or small groups of trees are harvested so a mature component of trees remain (Thompson, Probst, and Raphael 1995). Given the age of mature trees on the TNF, under even-aged management, it would take approximately 80-100 years for treated stands to begin to develop mature forest characteristics in this climatic region.

METHODS

Nesting Ecology

Monitoring methods

The terminology used to define reproductive success of goshawk territories follows recommendations by Postupalsky (1973), Steenhof (1987), Steenhof and Kochert (1982), and Woodbridge and Detrich (1994), with minor modifications. A **nesting territory** was considered an area that contained known nests where only one pair bred in a given year. A nesting territory was considered **occupied** if a pair of adult goshawks was observed perching or behaving defensively in the vicinity of known nests in the early part of the nesting season. A **breeding site** or **territory** was a location where I observed an adult in incubation posture or young in the nest. **Successful nests** or **territories** were those sites where I observed fledged young or fully feathered nestlings within 7-10 days of fledging. Territories contained either single nests or a **nest cluster** which I defined as all nest trees that were found within 1.2 km of each other and occupied by only one pair of goshawks in a given year. I used the distance of 1.2 km as this was one-half of the minimum inter-territory distance (2.4 km) measured during this study between two concurrently active goshawk nests. Except at one location, most nests within identified nest clusters occurred closer to each other than 1.2 km.

An **active nest** was defined as a nest which was used by a breeding pair in a given year during the study period. An **alternate nest** was a nest found at a known nesting area but not used by goshawks in a given year. Some of the nests I originally classified as alternate were occupied in subsequent years by goshawks; others were never used during the study period. These "unused" alternate nests were all in Douglas fir trees. I am confident that they were goshawk nests and not built by other raptor species, as they were similar in size and placement to confirmed goshawk nests. In addition, height and diameter of these trees were not significantly different compared to active nest trees (T tests, $p>0.05$; S. Patla, unpubl. data).

Goshawk nesting territories were opportunistically located between 1988 and 1993 using a variety of methods. These included annual surveys of historical nesting territories, surveys where goshawks had been reported in past years, follow-up on recent sightings, and broadcast surveys across portions of the TNF where no previous searches had been made. I checked all known nest trees, whether active or alternate, each year following the year of initial discovery. Nest monitoring was accomplished as unobtrusively as possible from the ground using binoculars or field scopes. Initial nest checks at most sites were completed between early May and mid-June, during the incubation and early nesting periods.

If none of the known nests within a territory were occupied, I returned one or two times between June 15 and August 15 to search for new nests using conspecific broadcast calling survey methods (Kennedy and Stahlecker 1993, Joy et al. 1994). Calls were broadcast every 200-300 m along parallel transect lines placed 250-300 m apart. I used the goshawk alarm call during the nestling period, and a combination of the alarm and the wail call during the fledgling period. Calling tapes were obtained from Sullivan Recording, 1390 Frank Hill Road, Ashland, OR 97520. Tapes were made at goshawk nest sites in northern California (B. Woodbridge, USDA Forest Service biologist, Klamath NF, pers. comm.). To broadcast calls, I used megaphones modified by Jim Garey, 516 99th Ave. NE, Bellevue, WA 98004-9413.

Given the large number and wide dispersion of territories, not all territories could be monitored with equal effort each year. Monitoring surveys were classified to one of three levels determined by the amount of area surveyed: Level A--1.6 km radius area surveyed around known nest trees, Level B--0.8 km radius area surveyed, and Level C--only stands containing known nest trees surveyed. If wind or rain conditions made hearing difficult beyond 300 m, surveys were not run. One or more follow-up visits were made to active sites to determine number of young produced.

I mapped nest locations on 7.5 USGS orthoquad maps or aerial photos. In 1993 and 1994, I also obtained GPS (Global Positioning System) positions for nest sites and other topographic features using a Trimble Basic Plus GPS unit and associated software. All GPS positions used for this analysis were collected in the 3D mode and differentially corrected to achieve the highest accuracy possible (GPS Pathfinder Basic™ Receivers Operating Manual). I collected a minimum of 180 GPS positions over a 2-3 minute period at each point location. Points were differentially corrected using data from a base station located on the Idaho State University campus, and then averaged to obtain a final, corrected position. I used GPS mapping software to measure distances between alternate nests within the same territories, and to determine geometric centers of nest clusters for territories that had more than one nest. To determine the precision of GPS nest positions, I replicated GPS readings at eight nest trees on different days. Replicates averaged 5.9 m (sd=3.0, n=8) apart which I considered acceptable given the dense canopy cover and mountainous terrain at most nest locations which can interfere with GPS readings (GPS Pathfinder Basic™ Receivers Operating Manual).

Calculating mean fledge date

I calculated mean fledge date using only nests (n=37) active between 1989 and 1994 for which I had either 1) good descriptions of nestlings so age could be determined using a photographic guide (Boal 1994), or 2) observations of nestlings shortly before and after fledging so fledge date could be calculated using the mid-point between these dates. To estimate mean date for onset of incubation and hatching, I backdated from the calculated fledge date, using an average incubation period of 32 days (Reynolds and Wight 1978), and an average fledging age of 39 days (Boal 1994).

Calculating productivity

I calculated goshawk productivity in two ways: as the number of young produced per the total number of breeding territories found, and the number of young produced per the total number of territories that were successful each year from 1989-1994. Thus, the first calculation includes all active nests in a year even those that failed to produce fledglings. The second calculation includes only those nests that actually produced fledglings. The total number of young produced each year included all nest sites found even those discovered late in the season during the post-fledging period. Mean annual productivity per breeding territory may be somewhat inflated because a higher proportion of successful nests are found during late surveys as nests that failed early would not be detected (Steenhof and Kochert 1982). Counts of young made after fledging occurs tend to underestimate number of young (Steenhof 1987), so I tried to obtain at least two separate counts of young at such territories on different days. Since some breeding territories were discovered in the post-nesting period, and the total number of monitoring visits per territory varied both within and between years, I did not attempt to use the Mayfield method, which uses the total number of observations made at nests during the incubation and nestling periods to determine percentage of nest success (Steenhof 1987).

To determine whether significant annual differences occurred in productivity, I compared productivity rates based on the number of young produced per successful nest between 1989-1994, For this comparison, I used the distribution free, multi-response permutation process (MRPP) procedure analogous to one-way analysis of variance (or t-test) available on Blossom software (US Fish and Wildlife Service National Ecology Research Center) (Slauson et al. 1991).

Calculating occupancy

Determining occupancy of goshawk territories is more difficult than for many raptor species due to the fact that goshawks are secretive nesters and often move to alternate nest locations each year, sometimes at a large distance from known nests (Woodbridge and Detrich 1994). Maximum distance between alternate nests used within the same territory has been reported to be occasionally as large as 2 kilometers; mean distances reported between alternate nests in study areas in northern California and Arizona fell slightly under 300 m (Reynolds et al. 1994, Woodbridge and Detrich 1994). It has been suggested that five years of monitoring a goshawk territory are needed to identify all nest stands that contain alternate nests for a given territory (Woodbridge and Detrich 1994). Occupancy rate of known territories, thus, should increase as a function of the number of years a territory is monitored (at least up to 5 years) and of the size of the area monitored (Woodbridge and Detrich 1994).

I calculated occupancy rate for individual nest trees, as well as for territories, to measure how often goshawks reused existing nests between 1989 and 1994. Each year a nest tree (whether alternate or active) was checked following the year of its initial discovery was counted as one nest check. To compute annual reuse rate of individual nest trees by goshawks, I divided the number of nests checked that contained goshawks by the total number of nest trees checked in each year. I also calculated the same rate for other raptor species found in goshawk nests.

To determine how often goshawks reused the same nest tree in consecutive years, I divided the number of times goshawks reoccupied the same nest in consecutive years by the total number of times goshawks renested within the same territories in consecutive years using the same or different nest tree. Percent occupancy of nest trees by other raptor species was determined as well.

To calculate reoccupancy rate of nesting territories, 1990-1994, I divided the number of breeding pairs found at known territories by the total number of territories surveyed regardless of the level of survey effort (Levels A, B, or C). Each year a territory was checked, no matter how many visits were made to that territory, was considered one **year-check**. I calculated a second reoccupancy rate based only on those territories surveyed at levels A and B, since alternate nest sites could have been missed at territories where only Level C surveys were completed. This second reoccupancy rate, based on Level A and B surveys only, should give a more accurate approximation of territory reoccupancy rate (Woodbridge and Detrich, 1994). I have included the first method for comparative purposes, and because monitoring surveys of goshawk territories continue in many places that I am aware of to rely only of checks made at known nest stands.

Analysis of the relation between weather and productivity and occupancy

Weather has been shown to influence reproductive success in a number of raptor species (Kostrzewa and Kostrzewa 1991b; Newton 1979; Newton 1986). Younk and Bechard (1994) attributed lower goshawk productivity in 1991 in Nevada to cold, wet spring weather. I used linear regression analysis to examine the relationship between productivity (1989-1994) and occupancy (1990-1994) with early season weather factors. I analyzed mean temperature and total precipitation for March, April, and May individually and, additive mean temperature and precipitation for pairs of months: March/April and April/May. Also included in the analysis were March snow depth and snow water equivalents (SWE). SWE is computed from snow density to determine percent water content of the snow pack. Weather data were obtained from the National Climatic Data Center, Asheville, NC 28801-2733 and the USDA Natural Resource Conservation Service, Driggs, ID 83422.

I did not include weather data from the months of January and February in the regressions as temperature and precipitation varied little in these months over the study years. For determining the relationship between occupancy and weather, I used results from monitoring surveys Level A and B only. Data variables were transformed as needed. I used the arcsine transformation for occupancy rate and SWE, and the square root transformation for productivity, snow depth and precipitation (Zar 1984). I did not transform temperature data due to negative values in some months. I also calculated Pearson correlation coefficients for all independent variables to determine the degree that variables were correlated with each other (SYSTAT, Wilkenson et al. 1990). I ran linear step-wise regressions using all variables as well as linear regression for each independent variable separately to determine their relationship with annual mean productivity and occupancy.

Analysis of goshawk prey

I collected pellets and prey remains within the vicinity of active nests. These were either frozen or dried, depending upon condition, and stored in labeled plastic bags. Prior to analysis, pellet samples were catalogued, assigned a random sample number, measured, and soaked overnight in a mild ammonia solution. I then broke the softened pellets apart and dried them for one to three days on mesh screens. Afterwards, I separated all bone fragments and intact feathers from fur. A sample of fur was retained for future analysis but was not analyzed for this study.

All prey remains and identifiable bone fragments and feathers from pellets were compared to museum specimens at the Idaho Museum of Natural History at Idaho State University for identification. To calculate biomass of prey species, weights were obtained from Steenhof (1983), Dunning (1984), Johnsgard (1988), Streubel (1989), and Johnsgard (1990). I used an average of adult male and female prey weights in calculations because most prey items were not classified to age or sex.

Observations from blinds were made at three nest sites in 1992 (two in lodgepole pine and one in Douglas fir habitat) during the last three weeks of the nesting period, and at one nest (Douglas fir) in 1993 during the entire nesting period. Small, camouflaged tents were placed on the ground within 30-40 m of the nest trees. Observations were made using a 20-60x power spotting scope, and observation periods, scheduled randomly throughout the day from sunrise to dark, averaged four to five hours. A single observer would record time, species, and estimated size of all prey deliveries. Detailed notes were also taken on behaviors and vocalizations of adults and young.

Habitat analyses methods

I completed habitat analysis at nesting territories occupied between the years 1989 and 1993. To ensure accuracy, measurements rather than estimates were obtained for most vegetation and topographic variables (Block et al. 1987) (Appendix A-1 and A-2). Data were collected either by myself, or by personnel I trained in 1992 and 1993. Although nest site data were collected over a period of five years, annual variation in the parameters measured was minimal given the mature characteristics of the forest cover at nest sites.

Level 1: Nest tree and nest site analysis

Level 1 analysis included a summary of nest tree characteristics and nest site physiographic features for 49 nest trees occupied by goshawks between 1989 and 1993 in the 27 current territories. Habitat measurements were collected at most nest trees within the same year that they were occupied by goshawks. Due to minor changes in techniques or equipment availability over the five year period, a few measurements at sites were obtained or retaken in later years.

All nest trees were classified by species and rated for their position in relation to the main canopy: dominant (extending above the main canopy layer), codominant (part of the main canopy layer), intermediate (below the main canopy), suppressed (shaded by the main canopy) (Society of American Foresters 1971). Nest trees were also classified to one of four possible topographic locations: flat ground or the upper, middle or lower third of a slope. Recorded nest characteristics included nest structural type, number and condition (live/dead) of support branches, nest aspect, and evidence of dwarf mistletoe (*Arceuthobium, sp*) infection. Nest aspect was measured with a compass from ground level standing directly below the center portion of the nest while facing out from the tree trunk. Distance of the nest structure in relation to the bottom layer of the green canopy (defined as where lateral green branches grew out from all sides of the main trunk), and distance of the nest from the main trunk were estimated from the ground.

Tree and nest height were measured using a Suunto clinometer (with percent and 66 ft topographic scales). For nest tree canopy cover, I averaged four measurements taken with a concave spherical densiometer (Forest Densiometers Model-A) at the cardinal directions while standing one meter from the base of the nest tree. I used a standard forestry tape to obtain tree diameter (dbh: diameter at breast height) Tree age was determined by counting growth rings on samples collected with an increment borer. I measured elevation using an altimeter or obtained readings from topographic maps. I determined slope aspect (compass) and slope percent (clinometer) standing at the base of a nest tree, facing down slope.

Level 2: Nest plot analysis

I collected nest plot data using a tree centered plot method at 44 of the 49 nest trees used by goshawks between 1989 and 1993. I did not take Level 2 measurements at nest trees located within the same territory if they were closer than 100 m to a previously measured tree or had visually similar plot characteristics. The plot radius was equal to the standard forestry length of one chain (66 ft) or 20.1 m. The resulting plot size equaled 0.127 ha centered at the nest tree. This plot size is substantially larger than the standard 12 m radius (0.04 ha plot) suggested for bird habitat studies (James and Shugart 1970) but I selected it considering the large size of the trees used by the goshawk for nesting. Larger plot sizes have been used in other forest raptor studies (Speiser and Bosakowski 1987, Gutiérrez et al. 1992). Total time to complete plot measurements ranged from 1.5 to 2.5 hours.

Within the plot, all live trees were counted and measured by species. I classified trees into one of five size classes based on dbh (diameter at breast height): saplings (3.8-7.6 cm), poles (7.6-17.8 cm); small (17.8-30.5 cm), medium (30.5-40.6 cm) or large saw timber (>40.6 cm). I selected these particular size categories based on categories used on the TNF and recent goshawk literature (Hayward and Escano 1989). Number of seedlings was counted or estimated from partial plot counts when more than 100 occurred in a plot. All snags greater than 3.8 cm dbh were measured and counted, and classified into similar dbh size categories used for live trees. To calculate overstory canopy cover, I averaged 16 spherical densiometer measurements: four each (one at each cardinal direction) taken at the 4 cardinal points located on the circumference of the plot circle. Average diameter of saw timber and snags, number of living and dead trees per hectare, basal area of live saw timber, and stand canopy cover were calculated for all plots.

I computed size categories of live and dead trees, ground cover height and number of mature downed trees only for one plot per territory. Ground cover height was measured in 1992 within four randomly selected 1 m radius plots within the main plot. I identified the genus and measured the height of the five tallest plants (forb or grasses) within these plots using a meter stick. The heights of all plants were averaged to calculate mean ground cover height. In 1993, I changed this method and measured ground vegetation height along four 20.1 m transects radiating out from the plot center. As the number of shrubs was extremely low in nest site plots, I did not collect data on shrub density or height (except at plots compared with random plots; see next section). For downfall, I counted all downed trees larger than 17.8 cm which had at least one-half of their length within the plot area. Numbers were converted to downed trees per hectare.

Determination of nest site selection using paired random plots

Data were collected at random plots similar in size to nest tree plots (20.1 m radius circles) within the estimated home range at 26 territories in 1993. I restricted sampling of paired random plots to within estimated home range areas to determine the habitat features important in goshawk nest site selection at the local or microhabitat scale (Hutto 1985). I specified that a random plot within a territory had to be located at a distance between 0.4 km and 2.4 km from the nest tree used in 1993 or in the last year prior to 1993. To avoid including potential alternate nest sites as random sites, I chose a minimum distance that was greater than the mean distance (322 m) measured between alternate nests found within nest clusters on the TNF (Patla and Trost 1995b). The maximum distance chosen was the radius (2.4 km) for a conservatively sized, circular home range of 1831 ha.

Based on the distance criteria, I selected bearings and distances using a random numbers table, and plotted the resulting random plot locations on aerial photos and orthoquad maps. If plotted locations fell in open areas or in stands of trees less than 12 m in height, a second random location was selected. To avoid visual bias in selecting plot centers, I used one of two methods. I either paced off the last few hundred meters while approaching the mapped plot point and used the mature tree (>12 m tall) closest to the final paced location as the plot center, or after reaching the approximate plot center, I would throw a stick into the air after circling with eyes closed. The mature tree closest to the fallen stick would be the designated center tree.

Habitat variables measured at random plots were similar to those described for Level 1 and Level 2 analysis except for the lack of measurements related to nest structure. The only difference in methodology was the collection of shrub data. For random plots and their paired nest plots, I measured shrubs along four 20 m transects radiating out from the plot center. The initial bearing for a transect was randomly selected and then the remaining three transects were run at bearings at 90 degree intervals. Along these transects, I counted the number of shrubs that touched my arms when held outright, at an approximate height of 143 cm. I used GPS measurements, aerial photos or orthoquad maps, to measure distance from nest trees or random plot center trees to the nearest forest edge (a definite ecotone where forest stands were no longer the dominant cover type that was apparent on aerial photos), permanent water source, and open road (county road or numbered Forest Service road that was ungated and appeared on district travel maps).

Statistical analysis of nest tree and nest plot data

For all nest tree and nest plot quantitative variables, descriptive statistics were calculated including mean and standard deviation (SD) or standard error (SE). I summarized data for all nest trees (n=49) and nest plots (n=44), and also completed a statistical comparison of Douglas fir and lodgepole pine nest trees and plots. To avoid pseudoreplication, I selected one nest tree randomly from each territory for this comparison (Hurlbert 1984). For statistical comparisons, I used multi-response permutation process (MRPP) procedure analogous to one-way analysis of variance (or t-test) available on Blossom software available through the USDI Fish and Wildlife Service National Ecology Research Center (Slauson et al. 1991). I chose to use MRPP statistical procedures because they are distribution free and work well for small sample sizes of ecological data that often are not normally distributed even after data transformations (Slauson et al. 1991, Potvin and Roff 1993, Squires and Ruggiero 1996). For comparison of paired nest sites and random sites, I used the MRPP permutation test for matched pairs (PTMP) to determine which variables differed significantly. Slope and nest aspect were analyzed using statistics for circular distributions: mean angle and Rayleigh's test for uniform distribution (Zar 1984), and Rao's spacing test (Batschelet 1981).

To determine the relation between habitat variables at the nest site and productivity (mean number of young fledged per nest), I used linear step-wise regression (SYSTAT, Wilkenson et al. 1990). I selected 14 independent variables judged most biologically meaningful that were not highly correlated with each other ® < 0.75): nest tree height; nest tree canopy cover; elevation; percent slope; basal area of living trees; mean sawtimber dbh; number of sawtrees per hectare; mean snag dbh; number of snags per hectare;

number of saplings per hectare; number of downed mature trees per hectare; and distance to edge, water and roads.

For this analysis I used productivity data from the same 27 conifer nests (one selected per territory) used for comparing Douglas fir and lodgepole pine nest sites. If a nest was active in more than one year, I averaged the number of young produced per year. I examined independent variables for normal distribution using histograms and normal probability plots, and transformed data as needed using arcsine, log or square root transformations (Zar 1984, Berk 1994). Productivity data were transformed using the square root transformation. Tests for multicollinearity, autocorrelation, and verification of regression assumptions were completed following procedures suggested by Berk (1994). Significance levels were set at 0.05 for all statistical tests except for the inclusion of variables in the stepwise regression model which was set at 0.15 (default value used in SYSTAT).

GIS analysis of spatial components within the home range (Levels 3-5)

Terminology and definitions for the larger spatial components that make up goshawk home range areas were taken from *Management Recommendations for the Northern Goshawk in the Southwestern United States* (MRNG) with slight modifications (Reynolds et al. 1992). Although these recommendations were written specifically for managing the goshawk in the Southwest, determination of the average home range size was based on data from numerous locations both in North America and Europe (see Table 1, MRNG). Since I did not have data on home range size for the study population, the estimate given in the MRNG seemed the most appropriate to use for this analysis. Three major spatial components of goshawk nesting territories (nest area, post-fledgling family area, and foraging area) were defined within the MRNG as mutually exclusive circular areas surrounding nest trees (Fig. 3a). For this study, I analyzed the nest area and post-fledgling family area as exclusive areas but did not separate out these smaller home range components from the larger scale foraging area as they constituted only 10 % of the total home range area (Fig. 3b).

Nest area (NA) in the MRNG was defined as 30 acres (12.1 ha) of forest with suitable physiographic characteristics surrounding a single nest. MRNG called for managing a total of three active and three replacement nest areas per territory since goshawk pairs often use between 2 to 4 alternate nest areas within their home range (Fig. 3a). Nest areas contain a high density of large trees and have high canopy cover to provide a stable micro-climate and protection from predators (Reynolds et al. 1992). For the GIS analysis, I used a contiguous circular buffer of 200 acres (80.9 ha) that was slightly larger in size than the total combined area of 180 acres (72.8 ha) specified in the MRNG for six active and replacement nest sites per territory. This circular area was centered at the nest tree, or the geometric center of nest clusters for territories that had more than one nest (Fig. 3b).

Post-fledging family area (PFA) was defined as approximately 420 acres (170 ha) surrounding the active and alternate nest areas (Fig 3a). It represents an area of concentrated use by the goshawk family after the young leave the nest but before they disperse. PFA's provide cover for the young from predators and contain sufficient prey so the young can develop hunting skills (Reynolds et al. 1992). For delineating PFA's, I created a GIS circular buffer area 600 acres (243 ha) in size centered at individual nest trees or nest clusters, and subtracted out the 200 acre (81 ha) core NA. The total area for the PFA thus equaled 400 acres (162 ha), slightly less than the 420 acres (170 ha) called for in the MRNG (Fig 3b).

Foraging area in the MRNG was defined as 5400 acres (2185.4 ha) surrounding the PFA that provide foraging habitat for adult goshawks (Fig. 3a). Attributes thought to be important for foraging habitat include large trees, open understories, interspersion of forest age classes, downed logs, woody debris, and openings with shrubs and herbaceous vegetation (Reynolds et al. 1992). For this study, I defined and analyzed the foraging area as an entire 6000 acre (2428.2 ha) circular area centered at nest clusters. I did not subtract out the core NA and PFA areas because they comprised only 10% of the total area. Also it is likely that some foraging by adults occur within these core areas (Kennedy et al. 1994). The size of the FA analyzed was not equal for all territories because some of the analysis circles included lands outside of the TNF boundary that were not classified in the GIS database.

To facilitate forest-wide analysis for revision of its 1985 Forest Plan, the TNF staff developed ARC/INFO GIS coverages for the entire TNF between 1992 and 1995. The vegetation GIS layer was constructed using standard Forest Service silvicultural examination data collected for discrete compartments (stands approximately 800-1000 acres in size (324-405 ha) (USDA Forest Service 1984). These data had been entered into an Oracle database based on defined attribute rules (Gerber 1992). Landsat images were used to classify vegetation in some areas of the TNF not covered in the forest stand database (Fred Straus, TNF GIS coordinator, pers. comm.). Vegetation coverages for each of the five districts on the TNF were reviewed for errors by district personnel and corrected as needed. Some points were ground-truthed, but the total area checked in this way was not quantified (Mark Orme, TNF Forest Plan Biologist, pers. comm.).

In the GIS attribute rules, a forest compartment (polygon) was classified as a pure stand (i.e. single tree species) if inventory plots contained 85% or more of that species based on density calculations (Appendix B). If Douglas fir and lodgepole pine occurred within a compartment together, both at less than 85%, the compartment was classified as a mix (MX) stand. Also distinguished were compartments which contained Douglas fir and/or lodgepole pine with a component of either alpine fir and/or Engelmann spruce (MX3).

The TNF vegetation database included a size class rating for average tree dbh of forested polygons (Appendix B). Minimum size for mature trees was 7 inch dbh (17.8 cm) for lodgepole pine and 8 inch dbh (20.3 cm) for all other conifer species. To be classified as mature sawtimber, polygons had to contain at least 98 lodgepole pine/ha, 37 Douglas fir/ha, or 74 mixed conifer trees/ha, live or dead of the appropriate size. Polygons classified as pole (3-6 inches or 7.6-17.8 cm dbh), sapling (1-2.9 inch or 2.5-7.6 cm dbh), and seedling (trees 6 inches or 15 cm in height to 0.99 inch dbh or 2.51 cm) had to have a minimum of 346 live or dead trees/ha (lodgepole pine and subalpine fir) or 297 trees/ha (Douglas fir and aspen). Stands classified as "non-stocked" contained seedlings less than

15 cm in height, or had less than 346 seedlings/saplings per ha (lodgepole pine and Douglas fir) or 297 seedlings/saplings/ha (Douglas fir and aspen).

Other attributes included in the TNF GIS database were stand age, density of live and dead trees, and presence of whitebark pine and aspen. Since stands were not classified consistently for these attributes (Fred Straus, TNF GIS coordinator and John Councilman, TNF silviculturist, pers. comm.), however, I did not include these attributes in my analysis. Stand canopy cover was not included in the vegetation database so I could not analyze this parameter although it is an important characteristic in evaluating goshawk nesting and foraging habitat (Crocker-Bedford and Chaney 1988, Reynolds et al. 1992).

Non-forest land in the GIS database was classified into one of 12 categories: mountain brush, willow, mahogany, grass, grass/forb, grass/sage, grass/brush, tall sage/grass, tall sage/mountain brush, bogs/ponds/lakes, wet meadows, or rock/talus/barren (Appendix B) (Gerber 1992).

The ARC/INFO buffer command was used to create three circular buffers for each territory: Level 3 analysis--80.9 ha nest area (NA), Level 4 analysis--242.8 ha post-fledgling family area (PFA), and Level 5 analysis--2428.2 ha foraging area (FA) (Fred Straus, TNF GIS coordinator, pers. comm.). For each territory, I obtained a print-out listing the total acreage by cover type within each buffer. I combined GIS vegetation categories to obtain a total of five cover types for my analysis: mature sawtimber (size class 9), young sawtimber (size class 8), seedling/sapling/harvested (size classes 5,6,7 and previously treated stands), sage/shrub (all sagebrush and shrub categories) and open area (combination of grass, wetland, rock, or barren categories) (Table 1). The seedling category contains forest stands that had no upper canopy layer. I included in this category stands treated as shelterwood and seed tree cuts because they did not occur in enough territories to break out as a separate category. The seedling category thus includes all stands that were harvested, including clear cuts or partial cuts, within goshawk home range areas.

I created a separate spreadsheet for each spatial level (NA, PFA, and FA) which included total acres of each cover type by territory and then converted acres to percent cover. An overall mean for the five analysis categories at each spatial level was calculated based on averaging data from all 27 territories. Based on my knowledge of these home ranges, and an earlier analysis I had completed of PFA cover types at some territories using aerial photographs (Patla and Trost 1995b), I noted a few errors in the proportions of cover types calculated for territories on the Island Park District. The district supplied me with corrected figures for these territories based on recent aerial photographs (John Councilman, silviculturist; and Nancy Doyle, wildlife biologist, Island Park Ranger District).

At some territories located close to the TNF boundary, the PFA and FA buffers included a substantial percentage of unclassified private lands. For the incompletely classified PFA areas, I replotted territory positions used in the GIS analysis onto aerial photos and delineated the PFA boundary on the photo along with the TNF boundary. I classified private lands falling outside the TNF boundary but within the PFA into one of the designated five cover types. To obtain areas for each patch, I used the dot grid method (USDA Forest Service 1988). These classified areas were then added to the GIS PFA areas to calculate final percent cover.

For the incomplete FA's, I included only Forest Service lands classified by the ARC/INFO vegetation coverage rather than attempt to classify thousands of hectares of private land using out-dated aerial photos. The size of the FA analyzed was smaller than the specified 2428 ha for over half of the territories analyzed. Because for management purposes the FS can consider only those portions of goshawk territories which fall within their jurisdiction, it seemed appropriate for the FA analysis to include only FS managed lands.

Analysis of the relation between habitat cover types and reproductive success

I used linear step-wise regression analysis (SYSTAT, Wilkenson et al. 1990) to determine whether productivity and occupancy were related to percent cover types within the different analysis areas surrounding nest trees (NA, PFA, FA). To calculate productivity, I used the average number of young produced per nest attempt at 27 current territories between 1989 and 1995. To calculate occupancy, I used only the subset of territories (n=22) that had been monitored at survey Level A or B for at least 3 years between 1989 and 1995. Habitat conditions at some territories substantially changed over the monitoring period due to timber harvesting within home range areas. At territories that underwent harvesting, I calculated occupancy and productivity using only the post-harvest period to reflect current conditions.

Percent cover and occupancy data were transformed using the arcsine function (Berk 1994). Productivity data were left untransformed as a square root transformation did not improve the distribution. Because within the NA and PFA mature forest cover predominated, many territories had little or no measurable amounts of the other four possible cover types. To avoid inclusion of variables in the regression model that consisted mainly of zeros, I decided to include only cover types that were present within at least 18 territories (67%) for each spatial analysis level. I checked for correlations between independent variables using Pearson's correlation coefficient and included variables that were not highly correlated ($r<0.75$) (SYSTAT, Wilkenson et al. 1990). Tests for multicollinearity, autocorrelation, and verification of regression assumptions were also completed following procedures suggested by Berk (1994). Significance levels were set at 0.05 for all statistical tests except for the inclusion of variables in the stepwise regression model which was set at 0.15 (default value used in SYSTAT).

In addition to regression analysis, I also compared percent cover types between high (> 50%) and low (≤50%) occupancy territories at the NA, PFA, and FA analysis levels using the MRPP statistical test analogous to the t-test (Slauson et al. 1991). I decided post-hoc to conduct this analysis due to the fact that the relative lack of variation in the most common cover type, mature forest, made it difficult to examine the relationship between reproductive success and cover types using regression analysis. In addition, I also compared productivity of territories that contained predominately Douglas fir/mixed conifer habitat within the home range area to territories in lodgepole pine habitat to determine if productivity differed in relation to floristics.

Analysis of effects of timber harvesting on nesting habitat

For my analyses on the effects of harvesting, I focused on one factor that is of major biological relevance for nesting goshawks and that could be measures at all territories: the reduction of mature forest cover within different spatial components of the estimated home range area. To evaluate the overall effects of timber harvesting on goshawk nesting habitat a number of additional variables could be considered including timing and scale of individual sales, and the total number of sales that have taken place in a particular area. At goshawk nesting territories found in the Island Park area, a confusing array of overlapping sales (lodgepole pine clearcut harvests and firewood harvesting) have occurred over the past 30 years. At many goshawk territories in the Centennial Mountains, harvesting (predominately Douglas fir shelterwood or seed tree cuts) has taken place fairly recently, between 1987-1992. How individual timber sales were planned and carried out has varied considerably over the past 30 years as well (Hejl et al. 1995). Variations exist in unit size and configuration, amount of downfall retained, number and size of live trees retained in partial cuts, and post-harvest treatments between different timber sale areas. Consideration of other biological factors in timber management besides timber production became more important over the past decade such as protecting riparian zones and maintaining habitat for threatened, endangered and sensitive species. Beside variations in silvicultural treatments, the level of grazing by cattle and sheep pre- and post-harvest also varied between individual sale areas. Documenting and quantifying these factors would be impossible in most cases as records are often scanty or lacking completely especially for older sale areas. Ultimately, harvesting results in a complex of changes to a forest community that vary in intensity and scale at different nesting territories (McCarthy, Carrier, and Laudenslayer 1989).

To assess the impacts of timber harvesting on reproductive success, multi-year baseline data on productivity and occupancy should be obtained, and then post-harvest areas resurveyed over a number of years (McCarthy, Carrier, and Laudenslayer 1989). Such surveys ideally would not be initiated until four to five years following the end of harvesting activities. This would ensure that goshawks had adjusted to habitat changes and had not just returned for a few years out of fidelity to traditional sites (Crocker-Bedford 1990). Although I have included results comparing productivity and occupancy in pre and post-harvest territories, these results should be considered preliminary since the monitoring period was short (3 year minimum) and post-harvest equilibrium had probably not been reached at recently disturbed territories.

Analysis 1: Measuring habitat loss at known territories

To quantify how current silvicultural practices were changing goshawk nesting habitat, I determined how much area had been harvested within the NA, PFA, and FA at 10 territories where active goshawk nests were found either before or during the year timber harvesting was initiated. To determine the total area harvested using the GIS database, I calculated the total land classified as nonstocked (GIS vegetation database symbol 5), seedling (GIS symbol 6), or having been partially harvested (GIS tree species with a "1" prefix) (Appendix B). I added the estimated harvested hectares to the total hectares currently classified as mature to reconstruct conditions within home ranges prior to harvesting. To determine whether reduction of mature cover was significant at different spatial scales, I tested the null hypothesis that the proportion of mature forest cover was not different in the pre and post-harvest periods within the NA, PFA or FA (MRPP, Blossom Software, Slauson et al. 1991). To measure goshawk response, I tested the null hypotheses that productivity (number of fledglings per nest attempt) and occupancy were not different in the pre- and post-harvest periods (MRPP, Blossom Software, Slauson et al. 1991).

Analysis 2: Analysis of occupancy at post-harvest territories

For this analysis, I classified all territories found in timber harvest areas that had been monitored for a minimum of three years into low (<50% occupancy rate) or high (50% or greater) occupancy groups, and tested the null hypothesis that these groups had similar proportions of mature forest cover within each of the different habitat analysis areas (MRPP, Blossom Software, Slauson et al. 1991). I defined territories in timber harvest areas as those which had at least 5% of the NA and PFA in seedling cover (seedling cover type included seedling, unstocked and previously harvested stands--see Table 1). I also tested the null hypothesis that these groups had a similar average number of nest trees per territory because the number of known nest trees in a territory may influence the probability of finding a territory occupied (Crocker-Bedford 1990).

I also regressed occupancy in these post harvest territories against the proportion of mature forest cover within the NA, PFA and FA (step-wise regression, SYSTAT, Wilkenson et al. 1990). Percent cover types and occupancy rate were transformed using the arcsine transformation. Other procedures for regression analysis were followed as described previously in the section: *Analysis of the relation between habitat cover types and reproductive success.*

Analysis 3: Analysis of historical territories no longer used by goshawks

In 1992 and 1993, I completed intensive searches for nesting goshawks at three historical territories where goshawk nests had been found originally between 1981-1985. These particular territories were selected because trained biologists had documented the presence of nesting goshawks, and I could identify the stands where nest trees had been located even though the exact tree could no longer be identified. To survey these historical territories, broadcast calls during the nesting and fledgling periods were used to elicit goshawk responses, and all remaining forest stands within a 1.6 km (1 mile) radius of known nest sites were searched for alternate nests or other sign of goshawk presence. Observations of other raptor species and their nests were recorded as well. I summarized the proportion of vegetation cover types at the NA, PFA and FA analysis levels and tested the null hypothesis that the proportion of mature forest cover at each analysis area was not different from the high occupancy post-harvest current territories. Although the number of territories was low, and I cannot verify why goshawks abandoned these areas, I analyzed them as examples of territories where habitat loss may have exceeded thresholds necessary to maintain breeding pairs of goshawks.

RESULTS

Nesting Ecology

Description of study territories

I collected monitoring and habitat data at 31 goshawk breeding territories (Table 2, Fig. 2). These territories were found throughout the TNF in a variety of cover types and management areas. To protect confidentiality of nest sites, only general locations have been given. Territory identification numbers refer to the TNF district where nests were found (D1- D5), and a unique number for that district (Table 2). An additional 19 potential nest areas were not included in this habitat analysis (Appendix C). These included 9 territories where either active nests were discovered in 1994 or 1995 after collection of habitat data was completed (n=5), or nests located in remote portions of the TNF that were not included in the monitoring program due to logistical constraints (n=4). At 10 other potential territories, goshawks were seen during the breeding season but nest trees never located (n=8), or historical nest stands once used by goshawks had fallen down (n=2). Many of these 10 potential territories are located in timber sale areas that have undergone substantial modification since goshawks were originally sighted.

Twenty-seven of the 31 study territories (87%) were occupied by goshawks at least once during the current period between 1988 and 1993: 19 (70%) of these current territories were first documented in 1988 or subsequent years (status ="C" in Table 2), and 8 (30%) were active at least once both prior to and since 1988 (status ="H/C" in Table 2). I use the term "current" to refer to all 27 of these territories throughout the remainder of this paper. Four territories out of the total 31 (13%) were active before 1988 but not in the current period; these were classified as historical (status= "H" in Table 2).

Since territories were found opportunistically, suitable habitat in between territories was not surveyed and estimates of home range size based on nearest-neighbor distance could not be calculated with confidence. Distance between nest clusters ranged from 2.4 to over 20 km. Through additional funding obtained for another study, I was able to conduct one large-scale systematic survey in the Centennial Mountains in 1993 using broadcast calling methods to survey a 85 km^2 study area (Patla and Trost 1995b). Two nests were found located 7.5 km apart. Calculated home range area for these nests based on nearest-neighbor distance was 4418 ha. Density of nesting pairs within the survey area equaled 1 pair per 3030 ha of suitable habitat (i.e. mature forest habitat) or 1 pair per 4167 ha for the entire study area.

The dominant conifer cover type at breeding territories, based on GIS vegetation classification within estimated home range areas, was Douglas fir at 14 territories (45%), mixed conifer at 9 (29%), and lodgepole pine at 8 (26%) (Table 2). Within the home range area of 20 (64%) of these territories, some degree of timber harvesting occurred between

1971-1992; the remaining 11 (35%) were in undisturbed habitat outside of timber management areas or in areas where proposed harvests had not yet occurred (Table 2).

Sixteen (52%) of the study territories were discovered through activities associated with timber sale planning such as tree marking or wildlife surveys (visual searches for nests, hawks and other wildlife), 9 (29%) were found by chance encounters in locations outside of active timber sale areas, and 6 (19%) were located using systematic broadcast survey methods in the Island Park area and the Centennial Mountains (Table 2). Broadcast surveys were conducted both within and outside of active timber management areas.

Nesting chronology

I calculated a mean fledge date of July 15 (range July 1-Aug 3) based on data from 37 successful breeding pairs, 1989-1994. Based on an average incubation period of 32 days, and a nestling period of 39 days, I estimated mean date for onset of incubation to be May 5 (range April 20-May 20) and mean date for hatching to be June 6 (range May 22-June 21).

At one territory accessible early in the season (D5-11), I monitored the nesting area weekly starting in early March in both 1993 and 1994 to determine initiation time of breeding activities. I first detected goshawks in the nesting area during the last week of March, 1993, and the first week in April, 1994. In both years, initial sightings of goshawks corresponded with the emergence of local Unita ground squirrels (*Spermophilus armatus*) from hibernation. Pre-nesting observations of goshawks included adults vocalizing near former nest trees, and goshawks soaring or carrying sticks above the nest stand. Goshawks initiated incubation during the third week in April in both years. A particularly interesting observation during the pre-nesting period in April, 1993, was the sighting of a male goshawk 0.8 km from the nest stand chasing a pair of soaring red-tailed hawks (*Buteo jamaicensis*). There are few published observations that describe how goshawks establish and defend territories early in the breeding season.

Nest productivity

I documented 68 breeding attempts at 27 territories (2.5 attempts/territory) between 1989 and 1994 (Table 3). Sixty-two of these attempts (91%) were successful. A total of 132 young was produced, an average of 1.96 young per breeding pair or 2.11 young per successful nest (Table 3). Over the study period, 21% of nests produced 1 young, 49% produced 2, 27% produced 3, and 3% produced 4.

Six breeding attempts (9%) failed during the incubation or nestling period between May 27 to June 28. Annual failure rate averaged one nest per year (range 0-17% per year) (Table 3). At one site I attributed loss of nestlings to pine marten (*Martes americana*) predation as downy feathers were caught in the bark along the trunk below the nest, and a marten den was located within 30 m of the nest tree. Brood reduction occurred at three successful nests. In all three instances, I found a partially feathered, dead nestling under a nest tree in the latter part of the nestling period in July. These young either fell or were pushed from the nest. In both cases, they appeared to have struck the ground head first and died on impact.

Comparing mean annual productivity over the five year period 1990-1994, I found a significant difference between years (MRPP, p=0.027). Productivity was highest in 1994 (2.63 young/breeding pair) and lowest in 1993 (1.45 young) (Table 3). The proportion of nests that produced either one young, or three to four young fluctuated widely over the years studied. In 1994, the year in which productivity per nest was highest, 63% of the active nests produced three young compared to only 8% and 6% respectively in 1991 and 1993. In 1993, the lowest productivity year, almost half the nests produced only one young. During the study period overall there was an alternating pattern of high and low productivity years.

Productivity and weather

Regression analysis examining the relationship between mean annual productivity and spring weather variables (Table 4) indicated that productivity was most strongly correlated to precipitation levels in early spring, and to a lesser extent, temperatures. Using linear regression analysis, I found that the number of young produced per successful nest was significantly related to three individual factors: combined precipitation in March/April (negative relation, p=0.005, adj r^2=0.86), combined temperature in April/May (positive relation, p=0.046, adj r^2=0.590), and May precipitation (negative relation, p=0.041, adj r^2=0.612).

Using stepwise regression analysis, both March/April precipitation (p=0.009) and mean April temperature (p=0.058) entered the final model: y=1.967 -(0.178)(March+April precip) + (0.019)(April temp), (p=0.005, F=51.857, adjusted r^2=0.953, SE=0.024, n=6). Figure 4 shows regression plots for these two variables.

Study years tended to have either cold and wet, or warm and dry springs as indicated by high correlations between the weather variables tested: mean temperatures for the months of March, April and May tended to be positively correlated while temperatures during this same time period tended to negatively correlated with total precipitation (Pearson correlation) (Appendix D). Wet, cold weather could affect goshawk productivity directly due to mortality of nestlings, or indirectly, due to decreased prey availability or abundance (Newton 1976).

Nest clusters and loss of nest trees

I documented the existence of 89 alternate and active goshawk nest trees between 1980 and 1994 at the 31 study territories (mean=2.9 trees/territory) (Table 5, Appendix E). Sixty-four of these nest trees (72%) were occupied by goshawks at least once between 1980 and 1994 (Table 5). For 25 alternate nests, I did not know year of construction or occupancy (Table 5).

I determined from historical records that five older nest trees were lost between 1986 and 1991; three were harvested and two apparently blew down. An additional nest tree found in 1983 died in 1993, but remained standing. In addition, four current nest trees were lost during the study period; two were blown down and two harvested (Appendix E). Considering all losses, ten nest trees (11%) were lost between 1986 and 1994, 50% from natural causes and 50% due to harvesting (Table 5). This equals a loss rate of 0.9 nest trees per year. This was undoubtably a conservative estimate since prior to 1989, when active nests were discovered in timber sale areas, searches for alternate nests were usually not undertaken.

The number of nest trees found per territory ranged from one to seven (Table 5). Alternate nests within the same territory usually were found within a contiguous forest patch, often along the same slope, or in an adjacent first-order or intermittent/ephemeral drainage. At one territory where I found the largest number of alternate nests (D1-06), nest trees were located over 1 kilometer apart in two non-contiguous untreated patches of mature forest habitat separated by a natural meadow and by harvest units that had been thinned twenty years previously.

Average distance between alternate nest trees used by breeding pairs within the same territories in consecutive years equaled 285 m (SE=48 m, range 42-904 m, n=24). Average distance between alternate nests used over a two year interval was 462 m (SE=124 m, range 170-1074, n=7). Combining these two categories, mean inter-nest distance equaled 325 m (SE=47 m, n=31). Only 4 active nests (13%) were located within 100 m of a previously used nest tree (Fig. 5). Nineteen nests (61%) were located between 100 and 400 m from a previously used nest tree, and 8 (26%) over 400 m (Fig 5). The largest distance between nests found active within one or two years measured 1074 m. If monitoring of territories depended only upon visual checking the last known nest, a majority of occupied nest sites would have been missed.

Considering all alternate nests found, whether used by goshawks or not during the current period, average distance between the most widely separated alternate nest trees in a cluster equaled 498 m (Table 6). The area of a circle with this radius equals 78 ha which turned out to be nearly identical to the size of the nest area I selected to use for habitat analysis. Mean inter-nest distance between active nests, and the largest distance measured between alternate nests in a cluster were undoubtedly biased low due to variable survey effort at territories and the fact that surveys never exceeded a 1.6 kilometer radius beyond known nests. Goshawks have been reported to use alternate nests in consecutive years spaced as far as 2.1 kilometers apart although distances this great appear to be the exception (Woodbridge and Detrich 1994).

Use of goshawk nests by Great Gray Owls

I found Great Gray Owls nesting within active goshawk territories on 13 different occasions in eight different territories. Four of these territories (50%) were in post-harvest areas. At one location, the owls nested in a broken top snag but the other breeding pairs of owls all used alternate goshawk nests. Mean distance between active hawk and owl nests was 395 m (SD=257, range=111 to 882 m). Goshawk nests failed twice (2/13=15%) but all owl nests were successful. The two goshawk nests that failed, one at hatching and one in the early nestling period, were located 142 m and 282 m from an owl nest. In one territory, I found a Great Gray Owl nesting in a goshawk nest that had obviously been built up by hawks earlier in the season. Goshawks used another nest within the territory that same year. In Europe, Great Gray Owls often nest in goshawk stick nests, and owls can take possession of nests that goshawks start to repair in the pre-nesting season (Höglund and Lansgren 1968; Pulliainen and Loisa 1977). The two species are considered highly competitive in Europe (Mikola 1983).

Reuse of individual nest trees

Between 1989 and 1994, I obtained at least one year's monitoring data (range 1-6 years) for 76 of the 89 nest trees documented (Table 7). The 13 trees I did not obtain data for included seven lost prior to the study period (see previous section on *Nest clusters and loss of nest trees*), and six found in 1994, the last year of the study period (Appendix E). I completed a total of 229 nest checks between 1989 and 1994 at the 76 monitored nest trees (mean=3.0 checks/nest, SD=1.5) (Table 7). Thirty-nine of the monitored nest trees (51%) were checked a minimum of three years. I calculated a reuse rate based on both the total number of nest checks completed, and the number of times an individual tree was used over the six year period. The first rate gives the probability of finding a previously identified nest tree reoccupied in a given year; the second rate gives the probability of finding a particular nest tree reoccupied over the entire study period.

Out of 227 total nest checks completed during the six year period, I found raptors occupying nests 47 times (21% reuse rate). Goshawks were found 18 times (8% reuse rate) (Table 7). The high rate in 1989 for goshawks (20%) was probably an artifact of the small number of nests monitored that year. Annual nest reuse rate by goshawks increased from 4% to 13% between 1990 and 1991-92, and then dropped back to 4% in 1994 (Table 7). This decrease in part reflects the fact that additional alternate nests were found each year within the same territories: the total number of nests monitored increased every year, but since only one per nest per territory could be used by goshawks in a given year, percent of use dropped overall. There was a decrease in territory occupancy rate as well, however, in 1993 and 1994, compared to 1992 (see next section).

Other raptor species were found 29 times out of the total 229 tree checks (13%) (Table 7) (Appendix E). Great Gray Owls (*Strix nebulosa*) accounted for almost all of these records; they were found 26 times (12% use rate). Three other raptor species were found on single occasions: Great Horned Owl (*Bubo virginianus*), Long-eared Owl (*Asio otus*), and Cooper's Hawk (*Accipiter cooperii*) (Appendix E).

Considering reuse rate of individual nest trees over the entire six year period, goshawks were found renesting 18 times in 16 different nest trees. Tree reuse rate thus equaled 21% over the five year period (16 trees reused out of 76 trees monitored). Other raptor species were found 20 times in nests over the same period (26% use rate) (Appendix E). Combining data from both goshawk and other raptor species, 28 of nest trees checked (37%) were found reused at least once after year of initial discovery.

Out of 46 instances when I documented goshawks renesting within the same territory in consecutive years, goshawks reused the same nest tree only twice (4.3%) (Appendix E: territories D1-04-2, D2-05-1). One of these nests failed the second year it was occupied for unknown reasons when the nestlings were 7-10 days old (D1-04-2). Goshawks reused three nest trees within a two year span (D1-06-1) (D1-11-1) (D4-01-1), one tree within three years (D5-10-1), and one tree after a six year documented hiatus (D1-09-1). The longest span of time I documented for a particular nest being reused by goshawks after the initial year of discovery was nine years (D1-06A-1). Great Gray Owls were more likely to reoccupy nest trees in consecutive years than goshawks. Two alternate nests were reoccupied by owls for four consecutive years (D1-10-2 and D5-03-1), and one for three (D1-09-1) (Appendix E).

Reoccupancy of territories

Between 1990 and 1994, I completed 123 year-checks at the 31 study territories (Table 8, Appendix F). (Note: a year-check was defined in *Methods* as the checking of one territory in a given year for occupancy. Even if more than one monitoring survey was made to that territory, it counts as only one year-check) Twenty-six territories (84%) were monitored for a minimum of three years: 15 territories were monitored for five years (48%), 7 for four years (23%), 4 for three years (12%), 3 for two years (10%), and 2 for one year (3%) (Appendix F).

I calculated reoccupancy of goshawk territories using two methods. The first was most inclusive based on results from all annual surveys (Survey Level A, B, or C) at territories each year following the year of discovery (see *Monitoring Methods* for definition of survey levels). Breeding pairs were found 51 times over the five year period: a 41% reoccupancy rate (Table 8). Reoccupancy rate increased from 1990 (33%) to 1992 (65%). The following two years, 1993-1994, however, occupancy decreased (Table 8). Considering the 72 year-checks of territories where goshawks were not found, 56% were minimal Level C surveys, 25% Level B surveys, and 19% Level A (Appendix F).

Since some active alternate nests were most likely missed using Level C surveys due to the large average distance between alternate nest trees (see previous section *Nest Clusters and the Loss of Nest Trees*), I also calculated reoccupancy rate based only on the number of territories that had been surveyed at Levels A and B (n=83), I found 51 territories reoccupied, an reoccupancy rate of 6% (Table 8). The annual trend in occupancy rates remained the same, however, with the highest rate (81%) occurring in 1992 and the lowest (42%) in 1994. Both methods indicated that reoccupancy of known territories dropped by 50% or more between 1992 and 1994 (Table 8).

Occupancy and weather

I found a significant negative relationship between mean annual occupancy rate based on survey Levels A and B and snow water equivalents (SWE) of the snowpack in March (occupancy =2.415 - (2.692)(Mar SWE)) (stepwise regression, $p=0.026$, $F=16.727$, adj $r^2=0.797$, $SE=0.089$) (Table 4). Although March snow depth and March SWE were strongly correlated (r=0.863, Pearson correlation, Appendix D), occupancy was not related to March snow depth (p=0.390). This discrepancy apparently resulted from data in 1991, a high occupancy year, where March snow depth was high (104 cm) but SWE relatively low (25%) (Table 4). The regression, upon inspection, was not strictly a linear relationship but resulted from clustering of three high (1990-1992) versus two low occupancy years (1993-1994) in relation to snow water equivalent data for March (Fig 6).

A low SWE in March can be an indication that the snow pack in March is disappearing faster compared to years with a high SWE in March (Glen Nelson, USDA Natural Resource Conservation Service, Driggs, ID 83422, pers. comm.) A longer lasting snow pack in the early spring season might inhibit goshawk foraging, resulting in poor body condition and abandoned nest attempts. A higher water content of snow might also have secondary negative effects on prey abundance and availability such as flooding of rodents burrows which could reduce population numbers. This apparently was the case in 1993, the year with the highest SWE (Table 4). In that year, a number of local farmers with land near the TNF reported to me that they observed few small rodents in buildings or fields.

Goshawk prey

I documented 186 different prey items (50% from direct observations at the nest and 50% from analysis of pellets or prey remains) taken by goshawks on the TNF. Twenty-five individual prey species were identified (Table 9). (Scientific names for prey species, and weights used to calculate biomass can be found in Appendix G). Mammals comprised 54% and birds 46% of the total number (Table 9). Calculated on a per weight basis, mammals made up 59% and birds 41% of the total biomass (Table 9). The six most important prey categories, each contributing 5% or more of the prey based on percent biomass, included snowshoe hare (30%), Unita ground squirrel (15%), Ruffed Grouse (13%), Blue Grouse (8%), unidentified grouse species (7%), and red squirrel (5%) (Table 9). In northern Arizona, lagomorphs were also the most important goshawk prey species with cottontail rabbits (*Sylvilagus* spp.) making up 26% of biomass based on observations of prey deliveries to nests (Boal and Mannan 1994).

Birds comprised a higher proportion (53%) of items identified using pellets and prey remains, while mammals were recorded more frequently based on prey deliveries to the nest (61%) (Table 9). Consistent with findings of Boal and Mannan (1994), using only pellets and prey remains to quantify goshawk prey most likely underestimates the importance of mammalian prey in the diet. In contrast to avian prey, goshawks often did not pluck mammalian prey, and consumed entire carcasses including bones and fur. Exceptions to this included the hind feet of snowshoe hare, and the tails of red squirrels which were frequently found in the vicinity of nests. To document mammalian prey from prey samples, hair analysis would need to be completed, a time consuming process that still would not provide good information on number of prey consumed.

Over 300 hours of observations from blinds were completed in 1992 and 1993. Two lodgepole pine nests (159 hours) and two Douglas fir nests (161 hours) were observed. The lodgepole pine nests were observed during the last three weeks of the nestling period in 1992. One Douglas fir nest was observed during the last four days of the nestling period in 1992; the other Douglas fir nest was observed during the entire nestling period in 1993. Adults delivered prey to the lodgepole pine nests (1-2 nestlings) at the rate of 0.25 items/hour (n=40). At the Douglas fir nests (3-4 young), delivery rate measured was 0.40 item/hour (n=64). At the Douglas fir nest observed during the entire nestling period, one prey species, Unita ground squirrel (*Spermophilus armatus*) accounted for 75% of all prey deliveries (n=48). Individual goshawks have been reported to specialize on certain prey species (Brown and Amadon 1968). This particular nest was located near the edge of the forest adjacent to natural sagebrush and shrub habitat, and near an undeveloped subdivision. Ground squirrels were abundant in the area. Adult males were observed bringing prey directly to nests on only two occasions when a female was absent. Usually the male perched a distance from the nest and called, giving a low-pitched single note contact call (Brown and Amadon 1968), The adult female responded with one or more wail-type calls before leaving the nest to retrieve a prey item. She either returned immediately to the nest and begin feeding the young, or disappeared for a period of five to ten minutes, most likely feeding herself first. On some occasions, a female left a nest without vocalizing and returned shortly afterwards with a partially consumed prey item which appeared to have been cached near the nest. I observed females feeding young throughout the entire nestling period, even when the young were almost fully developed. Twice, small live prey items were left by adults at a nest one or two days before the young fledged. In both cases, the young goshawks appeared to have trouble coordinating their feet to firmly grasp and kill the prey.

At the Douglas fir nest observed in 1992, the smallest of the four nestlings remained in the nest five days after his siblings fledged. The adults continued to deliver food to the nest, and the three fledglings returned to the nest early each day to feed and sleep, departing in late afternoon or evening to spend the night elsewhere. If I had made observations at this nest only during the mid-portion of the day, I would have assumed that none of these young had fledged. Continued feeding at the nest ensured that the youngest bird was fed adequately until it could also fledge.

In 1992, nest observers recorded no acts of physical aggression between siblings in the nest except for very brief incidents of pecking or grabbing prey. At the nest observed in 1993, the largest chick vigorously attacked its two smaller siblings four different times during a 4.5 hour period on June 7 when the chicks were approximately 12 days old. Heavy rain had fallen during the previous two days and the weather was cold and windy. During this time period, the male made no prey deliveries to the nest. The young appeared to be hungry and could be heard food-begging even when the hen settled down in a brooding position over them. The attacks occurred only when the hen left the nest for periods of time. The largest chick repeatedly struck the other two on the head with his bill, and dragged them back into the nest bowl when they attempted to escape by crawling up onto the rim of the nest. The chicks sustained no obvious injuries, and no other attacks were observed during subsequent observations. All three young survived to fledge. Siblicide related to food stress has been observed at goshawk nests (Boal and Bacorn 1994).

At this same nest in 1993, I observed the adult female chasing Red-tailed Hawks out of the nest stand on two different occasions, June 8 (young two weeks old) and July 8 (first day young observed out of the nest). Nestlings appear to react to other potential avian predators, Common Raven (*Corvus corax*) and Cooper's Hawk, near the nest by becoming silent after hearing vocalizations. The first incident was on July 5 when the female was not in attendance. Two ravens perched close to the nest and called loudly for a few minutes, then departed. Later on the same day, a Cooper's Hawk called from approximately 150 m from the nest. The young goshawk immediately lay down and ceased food-beg calling.

Visual observations of foraging goshawks, even of radio-tagged birds, are fairly rare given the remote habitat and secretive behavior of the goshawk. During the course of this study, I observed goshawks hunting ground squirrels in open areas of grass or sage meadows at three different locations. Goshawks approached ground squirrel areas flying just above the ground and landed near burrows, causing the rodents to draw back into their holes briefly. While the squirrels remained underground, the goshawk would run and position itself closer to a burrow or hide near the base of a sagebrush or small tree. Goshawks remained standing still in the open (or hidden from sight in cover) for a few minutes and then changed positions either by running across the ground or flying low for short distances towards other burrows. If prey was secured or after an unsuccessful foraging bout, a goshawk would fly directly to nearby stands of aspen or conifers. I observed one ground hunting episode that lasted a total of 45 minutes, but most were much shorter, 5-15 minutes in length. While standing in the open, goshawks often rotated their heads so they could scan the sky above. These foraging techniques differed greatly from Red-tailed Hawks which hunt ground squirrels and other prey by soaring and stooping or from perches (trees or poles) (Johnsgard 1990).

Habitat Analysis

Level 1: Nest tree and site

I documented a total of 60 nesting attempts at 27 current territories during the years, 1989-1993, and collected habitat data at 49 nest trees used by goshawks (Appendix H). Nest trees were not identified at seven sites where fledged young were found. Goshawks also used four nest trees more than once during the study period.

Four different species of nest trees were used by goshawks with Douglas fir out-numbering the other three species combined: 38 Douglas fir (78%), 9 lodgepole pine (8%), 1 trembling aspen (2%) and 1 Engelmann spruce (2%) (Table 10). Douglas fir trees tend to have stout, lateral branches that grow in a horizontal or upward position providing good structural support for nests. Most nest trees (94%) were either codominant (n=39) or dominant (n=7) within the nest stand (Table 10) . I found only one nest in a live tree of intermediate canopy position. Two nests (4%) were found in snags (Table 10). The majority of nest trees (53%) were located on the middle (n=22) and lower portions (n=14) of forested slopes (Table 10). Only 8% were found on the upper third of slopes (n=4), and 18% on flat terrain (n=9) (Table 10).

I classified goshawk stick nests into one of four possible structural categories: 15 platform (37%), 11 basket (24%), 7 broom (22%) and 5 broken crown (16%) (Table 11, Fig. 7). "Basket" nests were built on lateral branches that grew at an upward angle out from the trunk (Fig. 7A). These nests were deeper than platform nests, and wider at the top than bottom. "Platforms" were nests with a flattened appearance placed on horizontal, lateral branches (Fig. 7B). "Brooms" were nests placed on lateral branches either deformed by dwarf mistletoe infection or on "simulation brooms" (Hawksworth and Johnson 1989) (Fig. 7C). Simulation brooms in lodgepole pine trees appear similar to mistletoe brooms but occur in non-infected trees. Brooms consist of thick clusters of short green branches that make bushy nesting platforms. Some of the nests located on brooms were difficult to find and monitor as added nest material was difficult to see from the ground. "Broken crown" nests were in trees whose apical growing stem had been damaged; lateral branches at the top of the damaged stem grew upward providing a basket-type base on the top of the main trunk (Fig. 7D). Although this growth form occurs often in mature aspen trees, such a deformity was less common in conifers on the TNF. I found one broken crown nest in a suppressed, dead Douglas fir tree that was completely shaded by adjacent live trees (Fig. 7D). Another type of broken crown nest was in a codominant Douglas fir with a "U" shaped split trunk; the nest was built at the base of the "U".

Over a quarter of the nests were built on branches infected with mistletoe (27%) (Table 11). Overall, 38% of the nest trees would be considered defective from a silvicultural perspective due to the presence of mistletoe, brooms or broken crowns (Table 11). Such structural defects can provide nesting platforms even in trees that lack well developed lateral branches.

Most goshawk nests were found placed directly against a tree trunk. Only four out of 49 nests (8%) were placed at distances ranging from 0.6 to 1.2 m out from the main trunk on lateral branches. These were all broom-type nests. Nests occurred at an average distance of 1 meter (SD=1.9) below the main green canopy but ranged from 5 m below to 6 m up into the green canopy. Only 2 nests (4%) were found, however, placed totally within the main canopy. Almost half of the nests (47%) were placed directly at the bottom of the main canopy. The mean number of support branches for a nest was 3 (SD=2, range 1-7). Seven nests (14%) were placed on branches which were completely or partially dead.

Considering only those nest trees found on slopes (n=40), mean angle of slope aspect was 40 degrees (angular dispersion=50.7). The distribution was not uniform (p=<0.05, Rayleigh's test, Z=14.84). Nests tended to be placed in trees on northern and western aspects (Fig. 8A). Mean nest aspect, the position of the nest in relation to the trunk, was southeasterly whether calculated for all nests (mean angle=152 deg, angular deviation=71.5, n=44) or for only one nest per territory (134 deg, angular deviation=70.3, n=25) (Zar 1984) (Fig. 8B). Distribution was uniform, however, ($p > 0.05$, Rayleigh's test, z=2.136, n=44) (Fig. 8B).

Other Level 1 habitat variables are summarized in Table 12. Goshawk nests in almost all cases were found in large, older trees with dense canopy cover. Average values for all active nest trees (n=49) were: tree height 25 m, tree dbh 43.6 centimeters, nest height 13 m, nest to tree height ratio 53%, tree canopy cover 79%, and tree age 131 years (Table 12). Based on circumference measurements (dbh), all but one lodgepole pine nest tree (dbh=16.3 cm) would be classified as mature saw timber on the TNF. Mean elevation of nest trees was 2119 m (range 1860-2415 m). Nests were found on moderate slopes averaging 22% (Table 12).

For all Level 1 variables shown in Table 12 except nest height, Douglas fir and lodgepole pine nest trees were significantly different. Overall, Douglas fir nest trees were taller, larger in circumference, had greater canopy cover, and occurred at higher mean elevation and on steeper slopes. The average nest to tree height ratio was greater for lodgepole pine trees because mean tree height was less but nest height similar to Douglas fir trees. Since most nests were placed at the bottom or slightly below the green canopy, this indicated that canopy depth was less in lodgepole pine trees which corresponds with the lower average canopy cover measured for this species.

Mean distance from nest clusters to forest edge at the 27 current territories was 299 m; median equaled 122 m (Table 13). The large difference between the mean and median indicated a skewed distribution as illustrated in Figure 9A. Over half the nests (n=15, 56%) were located within 150 m of the forest edge, but the remainder were at greater distances, with 5 (19%) located more than 750 m from the edge (Fig. 9A). The greatest distance to edge recorded for a cluster was 1610 m. This suggests that goshawk population may be composed of birds exploiting different categories of prey species during the breeding season: one group may be focusing on species near or in edge habitats while more interior nesting pairs may depend more upon forest species. Additional data on prey use at forest interior nest sites would be needed to test this hypothesis.

The distribution of clusters located within 150 m of an edge is shown in Figure 9B: 12 nests (80%) were located 25 m or more from the forest edge. Mean distance to edge based on all nests in Figure 9B (n=15) was 55 m (median=42, SE=10). For nests located farther than 150 m from an edge in Figure 9A (n=12), distance to edge averaged 605 m (median=592 m, SE=119).

The type of openings closest to nests included: natural meadows at 14 territories (52%), clearcut harvest units at 7 (26%), select-cut harvest units at 5 (19%), and agricultural lands at 1 (4%). Considering only those territories with nests located within 150 m of an edge (Fig. 9B), 8 (53%) were closest to harvest units, and 7 (47%) to natural meadows. Almost all of the nest clusters within this latter group located closest to harvest units (n=7, 88%) were in areas of recent disturbance where units had been harvested since 1988. Of the territories located farther than 150 m from a forest edge, 7 (58%) were closest to natural meadows, 4 (33%) to harvest units, and 1 (8%) to agricultural fields.

Mean distance from nest clusters to permanent water sources was 552 m (median=343 m), and to open roads 1186 m (median =1290 m) (Table 13). I did not find a significant difference between Douglas fir and lodgepole pine nest clusters for any distance measure (Table 13). Douglas fir clusters tended to be closer to permanent water sources but farther from forest edge and open roads compared to lodgepole pine clusters (Table 13).

Level 2: Nest plot characteristics

I measured 44 Level 2 habitat plots at the 27 current territories (Appendix H). Plots were characterized by a large component of mature timber and relatively high canopy cover. Mean dbh of sawtimber was 30.8 centimeters, number of mature trees per hectare was 383, basal area of live mature trees averaged 27.7 m^2 per hectare, mean snag diameter was 15.1 centimeters, snag density was 286 per hectare, and stand canopy cover averaged 73% (Table 14). The dominant tree species at plots (accounting for $\geq$85% of all mature trees) was Douglas fir at 27 plots (61%), lodgepole pine at 9 (20%), a mixture of the two species at 5 (12%), and Douglas fir/Engelmann spruce at 3 (7%). Only three plots (7%) contained mature aspen trees.

Comparing one plot per territory (n=27), I found no difference between Douglas fir (n=20) and lodgepole pine (n=7) plots in overall density of sawtimber or snags (Table 14). Douglas fir nest plots, however, had significantly larger trees, and greater basal area and canopy cover (Table 14). Comparing size classes of live trees, Douglas fir plots had a significantly greater number of large and medium sized sawtimber; lodgepole pine plots had significantly more small sawtimber, pole-sized trees, sapling and seedlings (Table 15). Lodgepole pine plots also had a greater mean number of downed trees (134 vs 14 per hectare) (Table 15). Ground cover height between Douglas fir and lodgepole pine plots was similar averaging between 19-25 centimeters (Table 15). There were no significant differences between Douglas fir and lodgepole pine nest plots in the number of snags in any size category (Table 16). In both Douglas fir and lodgepole pine plots, the greatest density of snags was in the pole-size class (Table 16).

Level 3: Nest Area (NA)

The average size of the nest area analyzed was 80.4 ha (SD=0.32, n=27). Mature sawtimber was the most prevalent cover type whether calculated for all 27 current territories (68%) or for Douglas fir (72%) and lodgepole pine territories separately (57%)

(Table 17, Appendix I). Although the range of the percent of mature forest cover found at goshawk nest areas was large (24-100%), only three of the current nest areas (11%), all located in lodgepole pine salvage harvest areas, had less than 40% mature forest cover (Fig. 10A, Appendix I). Nineteen territories (70%) had 60% or more mature timber in the nest area; 9 territories (33%) had 80% or more (Fig. 10A, Appendix I).

Percentage of other cover types within the NA averaged: young sawtimber (3%), seedling (20%), sage/shrub (6%), and open areas (3%) (Table 17). Comparing Douglas fir and lodgepole pine nest areas, the only significantly different variable was percent of young sawtimber (Table 17). Lodgepole pine nest areas tended to have higher percent cover in young sawtimber (9% vs 1%) and seedlings (33% vs 15%). Douglas fir nest areas tended to have a greater proportion of mature sawtimber cover (78% vs 57%), sage/shrub habitat (8% vs 1%), and open area (3% vs 1%) (Table 17).

Level 4: Post-fledging Family Area (PFA)

To calculate the area of the PFA which surrounds the nest area required two steps. First, I obtained GIS data for circular buffers at each nest that averaged 240.8 ha (SD=2.0) in size. From each of these circular areas, I subtracted out the cover types found within the core nest area so ended up with an average PFA area of 159.8 ha (SD=2.8). The composition of the larger circles that included the core nest area, however, was nearly identical to the adjusted PFA's (Table 18): mature sawtimber averaged 66%, young sawtimber 5 or 6%, seedlings 17 or 18%, sage/shrub 7%, and open areas 4%.

As with the analysis of the nest areas in the previous section, the range of mature forest found within PFAs was large (16%-100%), but only two territories (7%) had PFA's with less than 40% mature forest cover, both in lodgepole pine salvage harvest areas (Fig. 10B, Appendix J). Seventeen PFA's (63%) had 60% or greater mature forest cover; 6 (22%) had greater than 80% (Fig. 10B, Appendix J).

Comparing the proportion of cover types between PFAs in Douglas fir (n=20) and lodgepole pine (n=7) habitats, lodgepole pine PFA's contained a significantly higher percentage of young forest (15% vs 3%), and seedling cover (31% vs 13%) (Table 19). PFA's in Douglas fir habitat tended to have a higher percentage of mature forest cover

(70% vs 52%), sage/shrub cover (9% vs 2%), and open areas (6% vs 0%,) but means were not significantly different (Table 19).

Level 5: Foraging Area (FA)

The defined foraging area, a circle encompassing 2428 ha, extended beyond the TNF boundary at 16 goshawk study territories (60%). The total area classified by GIS at each territory varied, ranging from 1243 to 2416 ha (Table 20). Mean area analyzed considering all current territories was 2124 ha (SE=70), or 87% of the defined foraging area (Table 20). Within the classified foraging area, mature forest cover predominated, with a mean of 61% for all territories (range 34-87%, Table 20). Only one territory (4%) had less than 40% cover in mature forest; it was located in a lodgepole pine salvage harvest area in Island Park (Fig. 10C, Appendix K). Nineteen (70%) of the FA's had 50 to 80% mature forest cover; four (15%) had 80% or greater (Fig. 10C, Appendix K). Proportion of other cover types listed in descending order was: seedlings/saplings (16%), sage/shrub (14%), young forest (5%), and open areas (4%) (Table 20).

Comparing Douglas fir and lodgepole pine foraging areas, Douglas fir foraging areas had a significantly higher percentage of sage/shrub cover (18% vs 3%) and open areas (4% vs 1%) (Table 20). Lodgepole pine foraging areas contained a significantly higher percentage of seedling/sapling cover (28% vs 12%), and also tended to have more young forest (10% vs 3%, Table 20). There was no significant difference in the percent of mature forest, although Douglas fir foraging areas averaged slightly higher than lodgepole pine (62% vs 58%) (Table 20).

Comparison of NA, PFA, and FA

I found few significant differences in proportions of cover types between different spatial scales (Table 21). Mature forest habitat predominated within all analysis areas, averaging over 60% (Table 21). Ranges of mature forest cover at each analysis level were large, but as explained in the previous sections, low values occurred in only a small number of existing territories, all in lodgepole pine salvage-harvest areas. The average amount of mature forest cover decreased slightly as the total area analyzed increased in size

(Table 21, Fig. 10). The number of territories that had 60% or more mature forest cover was 19 (70%) for the NA, 17 (63%) for the PFA, and 14 (52%) for the FA (Fig. 10A-C).

Proportions of all cover types were almost identical (±3%) in the NA and PFA analysis areas (Table 21). Comparing the core areas to the overall foraging area, I found a significantly higher proportion of sage/shrub cover in the FA compared to the NA (14% vs 6%), and the PFA (14% vs 7%); and a significant but only slightly higher proportion of open/grassland cover in the FA compared to the NA (4% vs 3%) (Table 21).

Habitat selection of nest sites

To determine microhabitat characteristics important in nest site selection, I compared habitat plots (0.127 ha) at known nest sites to random habitat plots located within estimated home range areas at 26 current nesting territories. A total of 22 variables were compared (Table 22). Based on the MRPP test for matched pairs, I found a significant difference between five variables (Table 22).

Compared to random plots, nest plots had taller center trees, greater basal area of mature live trees, greater overstory height, and more distance between the ground and the base of the live canopy (Table 22). They also were located further from the forest edge. In addition, nest plot aspects had a non-uniform distribution with nests concentrated on north and west-facing slopes compared to aspects at random plots which were uniformly distributed (Rao's spacing test, $p<0.05$; Fig 11). Also floristic analysis of tree species within plots indicated another significant difference: a higher number of nest plots had only one conifer species that comprised 85% or more of the mature overstory trees within a plot rather than a mixture of conifer species, or conifers and aspen. Twenty three nest plots (89%) were comprised of mainly Douglas fir or lodgepole pine compared to only 17 random plots (67%) ($p=0.048$, Pearson chi-square).

I also tested for differences in forest structure by comparing the size class distribution of live trees and snags between nest and random plots. Trees were classified into eight different size classes based on dbh: seven classes of 7.62 centimeter intervals ranging from 7.6 to 60.9 centimeters, plus a final class for trees greater than 60.9 centimeter dbh (Table 23). Snags were classified using the same size categories with one additional class, 2.5-7.6 centimeter dbh (Table 24). Nest plots had significantly more live trees in the 38.0-45.5 cm size class (Table 23). Differences in other size classes were not significant. There were no significant differences in the number of snags found within any size category (Table 24). The greatest density of snags in both random and nest plots was in the 7.6-15.1 centimeter dbh class.

In summary, nest sites could be distinguished from available mature forest habitat based on the presence of taller trees, larger basal area of living mature trees, greater number of live trees in the 38.0-45.5 centimeters dbh size class, and more open space between the ground and main canopy layer. Nest sites also tended to be located on north and west-facing slopes in stands dominated by a single conifer species, and be located farther from the forest edge.

Relation between productivity and nest site habitat variables

The number of young produced per nest, based on one nest randomly selected at 27 current territories, was related positively to plot basal area ($p=0.010$) and negatively to distance from the edge ($p=0.110$) ($F=5.806$, $p=0.009$, adj $r^2=0.270$) (linear step-wise regression). The final regression equation was productivity=1.649-(0.191)(edge distance) +(0.041)(basal area). These two variables explained only 27% of the variation in the number of young produced at the 27 nest sites, however. Linear regression plots of these two variables illustrate that the relationship between them and productivity is rather weak and of little predictive value, as a number of nest sites fall outside the 95% confidence limits (Fig. 12).

Variables excluded from the final model included: nest tree height; elevation; percent slope; nest tree canopy cover; mean sawtimber dbh; mean snag dbh; number of sawtrees, snags, saplings, and downfall per hectare; and distance to roads and water. A number of variables were not included in the regression analysis because they were strongly correlated with other variables (Pearson correlation > 0.75). Variables I found to be positively correlated included basal area and nest site canopy cover, basal area and density of large sawtrees, mean dbh of mature trees and density of large-sized mature trees, site canopy cover and density of medium-sized mature trees, overall density of mature trees and density of small-sized mature trees, and density of seedlings and saplings. Mean dbh of mature trees and number of small-sized mature trees were negatively correlated.

Relation of productivity and occupancy to cover types in the NA, PFA ,FA

For these analyses, I included monitoring data from 1995, as well as data collected between 1989 and 1994 summarized in Tables 3 and 8. Occupancy averaged 69% for 22 territories that had been monitored a minimum of three years between 1989 and 1995 (Table 25). Average number of young produced per nest attempt per territory calculated for territories over this same time span was 1.88 (SD=0.72, n=27) (Table 25). For step-wise regression analysis, I included only those cover types at each spatial level that occurred within at least 18 territories (67%) and that were not strongly correlated to another variable as described in *Methods*. Six cover types were included in the regression analyses: NA-mature cover, FA-mature, young forest, seedling/cut, sage/shrub, and open.

I found two variables significantly related to the average number of young produced per territory: proportion of mature forest cover within the NA (negative), and sage/shrub cover within the FA (positive) (stepwise regression, F=4.739, adj $r^2 = 0.223$, p=0.018). The regression equation was productivity=1.637 + 0.480 (mature forest FA)-0.263 (mature forest NA), based on percent of forest cover that had been arcsine transformed. Plots of these two variables against productivity shows a great deal of scatter, however, with many territories falling outside of the 95% confidence limits (Fig. 13), so the relationship, though significant, offers little predictive value.

For occupancy, only one cover type was included in the final model: sage/shrub cover within the FA (step-wise regression, F=6.879, adj $r^2 = 0.219$, p=0.016. The regression equation was occupancy (% arcsine transformed)= 0.702 + 0.974 (FA sage/shrub cover, % arcsine transformed). The regression plot appears to have somewhat less scatter compared to the previous regression plots between habitat variables and reproductive success, but a number of territories still fall outside of the 95% confidence bands (Fig. 14).

The fact that regression analysis failed to show a relation between occupancy and mature forest cover within the NA or FA most likely reflected the relatively low variation in mature forest cover within the data set (Newton 1977). After reviewing regression results, I conducted a post-hoc test to compare cover types at territories classified into high and low occupancy groups to determine if any differences existed between these groups (MRPP). I defined high occupancy territories as those that were occupied more than 50% of the years monitored, and low occupancy territories those occupied 50% or less. The high occupancy group (n=16) had an average occupancy rate of 81% (SD=16.4) and the low (n=6) 37% (SD=7.0) (MRPP, p=0.000). The number of nests found per territory for the high occupancy group (3.56 nests/territory, SD=1.55) averaged higher compared to the low occupancy group (2.33 nests per territory, SD=1.51), but this was not significant (MRPP, p=0.104).

Within the NA, high occupancy territories had significantly higher proportions of mature forest cover, and lower proportions of young forest and seedling cover (Table 26). Results were similar for the PFA: high occupancy territories had significantly more mature forest cover, and less young forest and seedling cover (Table 26). Within the FA, only one significant difference was measured: high occupancy territories had significantly less young forest cover (Table 26).

To summarize, regression analysis indicated the importance of sage/shrub habitat within the FA both for productivity and for occupancy. High occupancy territories were characterized by significantly greater proportions of mature forest cover within the NA and PFA, and significantly less young forest and seedling cover. High occupancy territories also had a lower proportion of young forest within the FA.

Comparison of productivity in Douglas fir and lodgepole pine territories

In addition to regression analysis, I completed a floristic analysis comparing productivity of territories in Douglas fir and lodgepole pine dominated home ranges. Breeding territories located in lodgepole pine habitat produced significantly fewer young per nest attempt (1.25 young, n=6) than territories in Douglas fir/mixed conifer habitat (2.08 young, n=21) (p=0.015, MRPP) (Appendix L). None of the lodgepole pine territories produced more than two young per active nest while territories in Douglas fir/mixed conifer habitat produced three young in 17 out of 58 nest attempts (29%)

(Appendix L). In addition, two Douglas fir territories produced 4 young in 1992. Thus, territories in Douglas fir /mixed conifer habitats contributed proportionately more offspring to the population both on an annual basis and over the entire study period. Whether this was related to actual productivity differences between cover types, or due to the proportionately greater amount of harvesting that had occurred in lodgepole pine dominated territories could not be determined given the available data set.

Effects of timber harvesting

Analysis 1: Measuring habitat changes at specific territories

Nesting goshawks were found prior or during the initiation of timber harvesting at 10 territories between 1985 and 1992. Prior to harvesting, these territories contained substantial mature forest cover: NA--90.0% (range 69-100%), PFA-86% (range 61-99%), and FA--80% (range 63-95%) (Appendix M).

I was able to measure changes at two Douglas fir nest plots (Level 2 analysis) located within units that were harvested using shelterwood methods in which a proportion of mature trees were retained for a few years post-harvest. At these plots located in two different territories, only 23% of the mature trees was retained post-harvest, resulting in canopy cover at the nest trees dropping from over 70% to less than 25%.

Within the three larger analysis areas (NA, PFA, and FA) at the 10 territories analyzed, mature forest cover was significantly reduced compared to pre-harvest conditions. Post-harvest these territories had: 57% NA (SD=13) (MRPP, p=0.0001), 60% PFA (SD=13)(MRPP, p=0.0010) and 61% FA (SD=10) (MRPP, p=0.0004). Proportionately more forest cover was harvested at the smallest spatial scales: NA = 33% harvested, PFA = 26% harvested, FA = 19% harvested (Fig. 15). The proportion of area harvested within individual territories ranged from 4% to 46% (NA) , 4 % to 47% (PFA), and 9% to 35% (FA). (Appendix M).

The minimum area harvested within an individual NA and PFA (4%) occurred at the same territory, D5-09. At this territory, a district biologist designated an untreated buffer of mature forest habitat to protect the estimated NA and PFA for a nest site discovered on the edge of a planned timber sale unit (Nadine Branson, USFS Wildlife

Biologist, Teton Basin District, Driggs, ID 83422, pers. com. 1990). Smaller, untreated buffers surrounding known nest sites were also retained at D1-09, D1-10, D2-02, D4-01, and D5-07, but the proportion of area harvested within the NA still ranged between 34% to 46% at these territories (Table 27--marked by asterisks, Appendix M).

In the post-harvest period, I documented goshawk use at eight of these 10 territories. Occupancy rates post-harvest ranged from 0% to 100% per territory (mean = 47%, SD=33) for monitoring periods that ranged from 2 to 5 years per territory (Table 27). Data on occupancy in the pre-harvest period was available for only four territories. Average pre-harvest occupancy was higher at these four territories (mean=79%, SD=25) compared to the post-harvest period, but was not statistically different, reflecting high variance and small sample numbers (MRPP, p=0.157, Table 27). Average number of young produced per nest in the pre- and post-harvest periods was also not significantly different (MRPP, p=0.631, Table 27).

To summarize, timber harvesting at known goshawk territories significantly reduced mature forest cover within the NA, PFA, and FA analysis areas. Reductions were greatest in the central part of the nesting territory within the NA and PFA, compared to the FA. Occupancy tended to be lower in the post-harvest period, but when nests were occupied, goshawks produced a similar number of young compared to the pre-harvest period.

Analysis 2: Occupancy patterns at post-harvest territories

Fifteen territories in post-harvest areas, i.e. those territories with 5% or greater seedling cover in the NA and PFA, that had been monitored a minimum of two years were classified into either a high (more than 50% occupancy rate) or low occupancy group (50% or lower occupancy rate) (Appendix N). The difference in occupancy rate between these groups, 72% vs 27%, was statistically significant (MRPP, p=0.002). High occupancy post-harvest territories had a greater proportion of mature forest cover at all three levels. This difference was significant at the NA level (MRPP, p=0.004), but not at the PFA or the FA levels (Table 28).

I also ran a regression analysis of occupancy as a function of mature forest cover at the three spatial levels. Occupancy was related to one variable: the percent of mature forest within the NA (stepwise regression, F=8.685, r^2 adj=0.354, p=0.011). The resulting regression equation was: occupancy, percent arcsine transformed = -0.030 + 0.106 (mature forest NA, % arcsine transformed). This regression for post-harvest territories (Fig. 16) appears to have more predictive value than the regression shown earlier between occupancy and cover types based on data from all current territories (Fig. 14). More territories fall within the 95% confidence limits (Fig. 16).

I also compared the number of nest trees found in the high and low occupancy groups. There was a significant difference. High occupancy territories contained an average of 4.0 nests (SD=1.8) and low occupancy 1.7 nests (SD=1.4) (MRPP, p=0.022, Appendix N). This could indicate either that breeding adults failed to return and build additional nests after the loss of some nest trees to harvesting, or that alternate nest trees were located at greater distances than the area surveyed and were not found. It also suggests that perhaps the lack of suitable nests trees might explain why the proportion of mature cover within the nest area is related to occupancy rates. The amount of mature forest cover retained around nest trees in the nest area may be a critical factor, rather than the absolute amount of mature forest cover retained in the nest area.

Overall trends of occupancy showed a different pattern for territories where no buffers or only minimal buffers were retained around known nest trees, and territories where known nests stands were protected by buffers of undisturbed mature forest habitat. In territories where known nest sites were given minimal or no protection, a lag response occurred: goshawks used a disturbed territory a few years post-harvest but then use appeared to drop off (Table 27). Nesting goshawks were found up to three years post-harvest but not in subsequent years (D1-04, D1-09, D1-11, D2-02, D5-07) (Table 27). At well buffered sites, goshawks were not present each year but were found nesting up to four or five years post-harvest (D1-10, D4-01, D5-09) (Table 27). Monitoring data from the 1980's for the historical territories D5-01 and D5-05 showed a similar type of lag response (Patla and Trost 1995b). The result of a lag response would be to inflate occupancy rates in the immediate post-harvest period. The determination of no significant difference in occupancy rates pre-and post-harvest reported for territories in the previous section might be a short term phenomenon.

Analysis 3: Historical territories no longer used by goshawks

In addition to analyzing current territories, I classified vegetation at three historical goshawk territories where goshawk nests had been found prior to my study (D3-02, D3-04, D5-01) (Table 29). Available monitoring data from the pre-study period for these three territories varied (Patla and Trost, 1995b, Table 10). At D3-02, a goshawk stick nest was found in 1981 by Great Gray Owl researcher, Alan Franklin, occupied by a Great Gray Owl. This stand, though scheduled for harvesting, was conserved. A district biologist returned to check this site for activity during the nesting season for 7 years but no goshawks were found (Gail Worden, former Ashton District Biologist). At D3-04, an active goshawk nest was found in a firewood sale unit in 1985. This site was also checked by Gail Worden over the next four years. Again, no goshawks were found. Both of these sites are located in the Island Park caldera area in areas of extensive salvage logging. The third territory was found in the Jackpine Loop area in the foothills of the Teton Range north of Driggs where lodgepole pine salvage harvests had also occurred in the mid to late 1980s. In this area, three active goshawk nests were found during timber sale related activities in 1980, 1981, and 1986 (Lew Becker, field notes, former Teton Basin District Biologist).

Intensive broadcast surveys in 1992 and/or 1993 within a 1.6 kilometer radius of former nest stands failed to find any evidence (goshawk sightings, feathers, pluckings, prey remains) that nesting goshawks currently reside in these historical territories.

Comparing, pre and post harvest conditions at these territories (Fig.17), the average proportion of mature forest harvested at each analysis level was large: NA 62% cut, PFA 45%, and FA 46%. Remaining mature forest cover at these sites averaged: NA 37%, PFA 49%, and FA 47% (Table 29). The highest proportion of mature forest cover found at any territory and any analysis level was 58% in the PFA of D5-01. Surveying these territories, I found few remaining mature stands that appeared to have adequate structure for nesting habitat compared to known nest stands on the TNF. Patches of mature forest left in these areas had either low canopy cover, low density of mature trees, small patch size, small diameter and height of remaining trees, or a combination of these attributes.

Other raptor species found nesting in these territories included Red-tailed Hawk (*Buteo jamaicensis*) (2 nests D3-04, fledglings D5-01), Cooper's Hawk (nest used by unidentified owl D5-01), and Great Gray Owl (nest D3-04). An active Common Raven nest (*Corvus corax*) was also found in D3-04. Other raptors sighted in these areas included Golden Eagle (*Aquila chrysaetos*) (D5-01), Red-tailed Hawk (adults seen all territories), Swainson's Hawk (*Buteo swainsoni*) (D3-02, D5-01), American Kestrel (*Falco sparverius*) (D3-04), and Turkey Vulture (*Cathartes aura*) (D5-01). Except for evidence of a Cooper's Hawk, all the other raptor species noted were those associated with open country rather than forest habitats (Johnsgard 1990). Inter-specific competition between goshawks and other raptors better adapted to utilize open areas may contribute to the absence of goshawks in post-harvest areas (Crocker-Bedford 1990; Kenward 1996).

DISCUSSION

Evaluation of the database

One of the difficulties in studying raptor nesting ecology and habitat is that study samples are often too small to be effective for evaluating results (Newton 1976). Factors that often make raptor nest sites hard to find (secretive behavior of nesting birds, low nest density, and nests located in remote and inaccessible places) are especially true of the goshawk. Broadcast surveys, the most widely used method for locating goshawk nests, are extremely time consuming. Response rates reported from broadcast surveys of previously unsurveyed areas equaled one response per 16.5 survey hours (1991) and 18.8 hours (1992) in northern Arizona (Joy et al. 1994), and one response per 22.8 hours in eastern Idaho (Patla and Trost 1995a). In both of these areas, approximately 30 km^2 had to be surveyed on average to find one active nest. To obtain an adequate sample for this study, I used every method possible given available resources to locate active nests. Part of my strategy was to include nests from as many different areas on the TNF to gain an understanding of the range of habitats used by the goshawk on this large National Forest.

Basing a habitat study on nests found opportunistically, however, may result in a biased estimate of habitat requirements (Siders and Kennedy 1996, Squires and Ruggiero 1996, Mosher et al. 1987). It has also been suggested that goshawk nest sites found mainly in the vicinity of active timber sales might bias data toward bigger and older trees (Hayward and Escano 1989).

Of the 27 current territories used in this study, nearly half (44%) were located outside of active timber sale areas. Only five of the 27 territories, however, were located in management areas classified as unsuitable for timber harvesting. Thus, 82% of the study territories (22/27) were found in areas on the TNF considered suitable for harvesting. Since 57% of the forested land on the TNF has been classified as suitable, the database appears to be biased towards nest sites found on lands managed for timber. However, given the definition of suitable forest land (see *Study Area: Forest Composition and Timber Management*) it is reasonable to assume that these lands would be more productive overall and contain more forest area structurally suitable for goshawk nesting habitat than areas classified as unsuitable. Also, since density of nesting raptors is related to soil productivity and overall prey abundance (Newton 1986), it is likely that a higher proportion of nesting goshawks occurs in areas on the TNF classified as suitable for timber production.

I used two approaches to evaluate bias from non-random selection methods or over-representation of nest sites from timber management areas. First, I compared nest sites at two Douglas fir territories found in 1993 during a large-scale systematic survey in the Centennial Mountains to Douglas fir nest sites found opportunistically in other areas of the TNF (n=37 nest trees at 15 territories). Comparing nest site and nest plot habitat parameters, the only significant difference was that nest sites found opportunistically were located closer to the forest edge (Table 30) (Patla and Trost 1995a). Distance to edge data presented in Figure 9 supports the idea that a disproportionate number of nest sites in the data set were found close to the forest edge. Interior nesting territories were probably under-represented, but this did not appear to bias measurements of nest site and nest plot structural and topographic features of goshawk nest sites. Considering the larger habitat analysis levels (NA, PFA and FA), territories found using systematic survey methods had very high proportions of mature forest cover within the estimated home range area (NA=100%, PFA=95%, and FA=80%) (Patla and Trost 1995a). My data set of nesting territories, if biased toward sites located near the forest edge, may also be biased toward territories that contained less mature forest cover due either to natural or human causes.

For the second evaluation of bias, I compared five current nesting territories found in management areas classified as unsuitable for timber management to 22 territories found in suitable management areas. The five territories in unsuitable management areas were located in the Beaverhead Mountains (2), Henry's Lake Mountains (1), and the Big Hole Mountains (2) (Table 2: D1-02, D1-03, D2-04, D5-10, D5-11). Only two variables were significantly different: nest sites in areas suitable for timber management tended to have larger nest trees (dbh =51.5 vs 35.2 cm; MRPP, p=0.014) and lower canopy cover within nest plots (69% versus 87%; MRPP, p=0.019) (Table 31). While this result appears to support the idea that nest sites found primarily in timber sale areas might be biased toward bigger trees (Hayward and Escano 1989), the average diameter and density of mature trees within nest plots were not significantly different.

Evaluations of potential bias in this data set, although based on a small number of comparisons, indicates that my analysis of goshawk nesting habitat data was not seriously biased. From a management perspective, the most serious bias appears to be the under-representation of interior forest nest sites.

Evaluation of monitoring data

There is a potential bias in the monitoring data, since initial checks at most territories occurred after the nest construction and early part of the incubation period. In some years, in fact, I did not check a few territories in outlying regions of the TNF until late July or early August. Monitoring later in the breeding season would not detect early nesting attempts by goshawks that failed. If there was a substantial number of such failures, the actual rates of territory reoccupancy could be higher than my data suggest (Steenhof and Kochert 1982).

To evaluate this potential bias, I evaluated when initial checks of territories were completed between 1989 and 1994. Initial territory check dates were classified into one of four periods relating to the chronology of events during the breeding season: pre-nesting (April to May 5), incubation (May 5-June 6), nestling (June 7-July 14), fledgling (July 15-August 15). Out of a total of 146 initial territory checks: 19 (13%) were completed during the pre-nesting period, 44 (30%) during the incubation period, and 54 (37%) during the nestling period. Only 29 (20%) were completed during the fledgling period when the probability of observing signs of failed nesting attempts such as freshly rebuilt nests, prey remains, or presence of unsuccessful breeding adults would be greatly reduced. The proportion of territories that were checked in the fledgling period was highest in the early years of the study when I had no field assistants (43% in 1989 and 1990, and 33% in 1991), and decreased substantially in later years: 7% (1992), 3% (1993), and 10% (1994).

In a two year study of 98 occupied nests in northern Arizona, 3% of nests failed prior to or during early incubation. An additional 6% each were lost during the incubation and the nestling period for a total failure rate of 15% from pre-incubation through the nestling period (Reynolds et al. 1994). On the TNF, I measured a combined failure rate of 9% in the incubation and nesting period. If failure rates are similar between the two areas, data from Arizona suggest that while the calculated rate of territory reoccupancy on the TNF would be higher if all territories could have been checked consistently between mid-April and early May, the increase in territory occupancy overall probably would have been less than 10%.

Nesting chronology

Nesting chronology on the TNF was very similar to dates reported elsewhere in the western United States (Table 32). Goshawks on average start incubation between mid-April to early May and fledge young in the early part of July (Table 32). There is a rather remarkable consistency of dates reported from over a wide geographical and elevational range

Incubation dates for other raptor species in the vicinity of the TNF that are potential nest site competitors ranged from early April for Great Horned Owl, first three weeks in April (peak April 10-11) for Red-tailed Hawk, mid-April to early May for the Great Gray Owl, and mid-May for Swainson's Hawk (*Buteo swainsoni*) (Franklin 1988; Whitfield and

Maj 1993; Smith 1994; S. Patla, unpubl. data). Great Gray Owl incubation overlaps most closely with the goshawk, leading to the greatest possibility for direct conflicts over nest sites. Although other studies have reported use of goshawk nests by Red-tailed Hawks and Great Horned Owls (Moore and Henny 1983, Crocker-Bedford 1990, Woodbridge and Detrich 1994), I recorded only one instance of a goshawk nest being used by a Great Horned Owl. As noted earlier, Great Gray Owls were found at 30% of the current study territories.

Productivity

The number of young fledged per active nest (1.96 young/nest, Table 3) falls within the range of values from older study sites in North America and Europe as summarized by Reynolds and Wight (1978). Most current study areas have reported fairly similar averages for number of young per active nest including 1.93 in northern California (Woodbridge and Detrich 1994); 1.9 in northern Arizona (Boal and Mannan 1994), 1.8-2.0 in northern Arizona (Reynolds et al. 1994); 1.2-2.8 in northern Nevada (Younk and Bechard 1994), and 0.7-2.2 in eastern Oregon 0.7-2.2 (DeStefano et al. 1994).

Percentage of successful nests reported for goshawks ranged between 80 and 90% at these same study areas, although results may have been biased high due to inability to check all nests in the pre- and early incubation periods (Boal and Mannan 1994). Reasons for goshawk nest failure and nestling mortality could not be ascertained in most instances unless observations were made from blinds or by climbing nest trees. Boal and Mannan (1994) attributed 45% of nestling mortality to Great Horned Owl predation and 18% to falling from the nest. Woodbridge and Detrich (1994) reported 18% of nest failures resulted from Great Horned Owl predation and 18% from severe spring storms.

Similar to my findings, a correlation between cold, wet weather in the spring and low productivity has been reported from Europe for the goshawk, and for the European Sparrowhawk (*Accipiter nisus*). In Germany, number of young goshawks fledged per pair was correlated with April-May temperature, May temperature and rainfall days in May; and the percentage of laying pairs was negatively correlated with March, and March and April rainfall (Kostrzewa and Kostrzewa 1991a). No significant relationship with weather were found in June (Kostrzewa and Kostrzewa 1991a) or with winter weather factors such as temperature or snow cover (Kostrzewa and Kostrzewa 1991b). Newton (1986) reported a delay in sparrowhawk hatching date and reduction in total number of nesting pairs related to poor weather in March and April.

Direct negative effects of cold and wet weather on raptor productivity and occupancy during the pre-nesting and early incubation periods may include: increased energy expenditure by breeding adults and associated reduction in body weight; death of nestlings due to hypothermia, especially during the first week post-hatching; and reduction in prey availability and/or numbers resulting in reduced prey deliveries and starvation (Kostrzewa and Kostrzewa 1991a, Newton 1986). Rain has been shown to affect raptor breeding success differentially in Australia, resulting from plumage differences among species (Olsen and Olsen 1992). Weather appeared to be one of the most important limiting factors for reproductive success of tree nesting raptors compared to those nesting in more sheltered sites (Kostrzewa and Kostrzewa 1991a).

Few studies have been undertaken on the effects of weather on social behavior of raptors (Temeles and Wellicome 1992). The observation of sibling aggression during a period of wet weather and of reduced prey deliveries on the TNF indicates that the absence of the adult female from the nest during a time of food shortage may be a proximate cause of silblicide (see also Boal and Bacorn 1994).

The fact that good productivity (2-3 young produced) occurred at some nest sites on the TNF even in years of poor spring weather (Table 3), suggests that differences in vegetative structure and related microclimatic factors at some territories may create better protection for nests and offer more opportunities for foraging in bad years. Selection by the goshawk of dense canopy stands for nesting has been attributed to a sensitivity to insolation at nest sites (Hall 1984; Reynolds 1984). However, protection from snow, rain and wind in the early part of the season may be an equally important factor.

Occupancy of nests and territories

Long term studies of occupancy patterns at goshawk territories are rare in North America. In a few areas, historic territories discovered earlier have been resurveyed by researchers for occupancy, but data were not available for the intervening years (Bull and Hohmann 1994; Crocker-Bedford 1990). In the longest term study to date, Woodbridge and Detrich (1994) monitored goshawk territories in Northern California over an eight year period at three spatial levels: nest trees, nest stands, and nest stand clusters (all alternate nesting stands in a territory based on surveys within 1.6 km radius area of known nests). They reported a mean occupancy rate for individual nest trees of 49% (SD=11) at 26 territories over at least a 5 years period. Thirty seven out of 85 nest attempts (44 %) were in nests used the previous year. At territories monitored for at least five successive years, individual nest stands were occupied an average of 46% (SD=6) and entire nest stand clusters, 74% (SD=6%) of the years monitored. Nest stand clusters were the collection of all stands that were used for nesting in a territory.

Nest occupancy rates of individual trees on the TNF, calculated for all nests on a per year basis, was only 18% for goshawk. Recalculating nest occupancy based on nests monitored for five or more years resulted in an occupancy rate of 47% (7/15 total nests reoccupied at least once), similar to northern California (Woodbridge and Detrich 1994). Only 2 nest attempts (4%) on the TNF, however, occurred in nests used the previous year, and one of those attempts failed.

Reoccupancy of territories on the TNF based on all survey levels (A,B,C) was close to that reported for individual nest stands (equivalent to Level C surveys) in northern California (Woodbridge and Detrich 1994): 41% versus 46% respectively. Based only on territories surveyed at levels A and B (0.8 to 1.6 km radius area surveyed), the reoccupancy rate on the TNF increased to 61%, which was lower than the 73% reported by Woodbridge and Detrich (1994) for nest stand clusters. The lower rate on the TNF probably resulted from differences in survey effort. In northern California, 1.6 km areas were surveyed around each previously used nest, not just a subset of nests.

Three points are important in regard to the occupancy data. First, survey results and occupancy rates from the TNF and northern California show that occupancy rate is proportional to the amount of area surveyed around known nests. Monitoring based only on checks of known nest stands missed almost 30% of nesting attempts (Woodbridge and Detrich 1994). For my study, I assumed that I found a majority of active nest sites at territories surveyed either at Level A and B (within 0.8 to 1.6 km of known nests). If this assumption was not correct, then levels of occupancy may have been higher than what I reported here.

Second, large fluctuations were measured in annual occupancy rate on the TNF. Percent occupancy of territories in the best year, 1992, was nearly double compared to 1994, the lowest year (Table 8). Although productivity alternated between above and below average years, occupancy remained low for two consecutive years: 1993 and 1994. The fact that productivity was high and occupancy low in 1994 suggests that breeding birds failed to return to territories, indicating perhaps high mortality during the non-breeding season and a lack of floaters or unmated birds without territories in the population to replace breeding adults. The remarkable stability reported for many raptor nesting populations has been attributed to a ready supply of replacement breeders in a population (Newton 1979). Immigration of replacement breeders is thought to buffer declines in Northern Spotted Owl populations that have low adult survivorship rates (Burnham, et al. 1996).

Data on goshawk mortality during the non-breeding season are rare. Kenward (1996) has suggested that goshawks in North America may experience both greater food shortages and interspecific competition in winter compared to European populations (Kenward 1996). Radio-tagged adult goshawks nesting in southcentral Wyoming were found to migrate to Colorado in the winter; mortality of one male was attributed to eagle predation (Squires and Ruggiero 1995). Data are needed on winter ecology of goshawks to determine to what degree mortality during the non-breeding season influences occupancy of breeding territories. Color-banding studies are also needed to measure demographic parameters and replacement rate of breeding adults since little is known concerning the goshawk (DeStefano et al. 1994).

Third, although occupancy of nest trees was similar on the TNF and in northern California (47% vs 49% for nest trees monitored over at least a 5 year period), reoccupancy of individual nest trees in consecutive years was much lower on the TNF, 4% versus 44% (See Results: *Reoccupancy of Nest Trees*; Woodbridge and Detrich 1994). This could result from two interacting phenomena: differential availability of nest sites, and different predation pressures. Woodbridge and Detrich (1994) described their study area as intensively harvested and fragmented, with goshawks nesting in the remaining patches of mature forest. This type of harvesting would reduce and concentrate the total number of potential nest trees so goshawks might be forced to reoccupy the same nests more frequently. Although habitat fragmentation and concentration of nest clusters would appear to result in higher predation pressure compared to less fragmented areas, such habitat changes might actually reduce or eliminate interior forest mammals in the family Mustelidae that have been reported to prey on nesting goshawks such as pine marten (this study), fisher (*Martes pennanti*) (Erdman 1993) and wolverine (*Gulo gulo*) (Doyle and Smith 1994). Studies of nest box use by owls in Sweden showed that martens have spatial memory of nest locations and will predate boxes left in the same location in consecutive years (Sonerud 1985). Goshawks nesting in intact forests may switch nests not only because they have more choices for alternate nest sites, but also to avoid mammalian predators.

Goshawk prey

Goshawks are opportunistic foragers, preying upon a variety of different bird and mammal species (Reynolds 1992, Doyle and Smith 1994). On the TNF, however, over 72% of prey biomass consisted of four species: snowshoe hare, Unita ground squirrel, Ruffed Grouse and Blue Grouse (Table 9), and one male goshawk during the nestling period fed almost exclusively on ground squirrels. Decreases in the populations of these primary prey species due to natural cycles or man-caused disturbances may well explain some of the fluctuations observed in productivity and occupancy at breeding territories (Doyle and Smith 1994). In Finland, goshawk clutch size correlated with density of four tetraonid species which peaked every 6-7 years (Sulkava et al. 1995). Population databases on local prey species are not maintained by the Idaho Department of Fish and Game (Jeff Copeland, Non-game biologist, Idaho Dept. of Fish and Game, pers. comm.), however, so I could not correlate annual goshawk population fluctuations with prey cycles.

Habitat analysis

Nest sites

Goshawk nest tree and nest plot structural characteristics on the TNF were similar to those reported from other conifer habitats in the western United States outside of Alaska (Hayward and Escano 1989; Jones 1979; Marshall 1992; Reynolds et al. 1992). Nests were placed close to the trunk at or below the main green canopy with few exceptions. Almost all nests were placed in dominant or codominant live trees in mature stands but were usually not in the largest tree in a stand as reported by Reynolds (1989) and Squires and Ruggiero (1996). Nest plots were characterized by high tree density and canopy cover; plots were multi-storied in almost all cases with a fairly uniform upper canopy layer. Nest trees tended to be located in single species conifer sites on the lower and middle portions of moderate slopes with northwestern aspects.

The only published data on goshawk nest sites in Idaho were based on 17 nests in northern Idaho and western Montana (Hayward and Escano 1989). These nest sites were found over a broad geographic area encompassing two distinct climatic zones (on the east and west sides of the Continental Divide), and a wide variety of forest types. The majority of sites were found during timber sale operations. Since their plot size (0.04 ha) differed from that used on the TNF, I converted trees per plot to trees per hectare. Mean nest tree height, nest tree diameter, nest height and canopy cover were not significantly different compared to sites in Douglas fir and lodgepole pine habitats on the TNF (Table 33). Basal area on the TNF was significantly lower, however (Table 33). Comparing density of different size-classes of trees, the greater basal area in the more northern forests resulted from substantially more trees in the pole-sized (7.6-17.8 cm dbh) and small sawtimber categories(17.8-30.4 cm dbh) (Table 33). Density of medium (30.4-60.9 cm dbh) and large sawtimber (>60.4 cm dbh) was not significantly different (Table 33). This comparison, based on sites from a large area, indicates that goshawks in the northern Rocky Mountain region are selecting nest sites with very specific structural characteristics. Nest sites are characterized by large nest trees, high canopy cover and a component of larger-sized trees in the nest stand.

Nest site habitat selection

According to current theory, factors important in habitat selection by birds are scale-dependent. Recognition processes are thought to precede in a hierarchical (Hutto 1985) or branching fashion (Klopfer and Ganzhorn 1985). Responses to specific fine-scale floristic and structural vegetation attributes should be important in choosing nest sites within the larger home range area (Wiens and Rotenberry 1981).

Only a few goshawk habitat studies have included analysis of habitat selection based on comparisons of nest sites to random sites (Hall 1984, Speiser and Bosakowski 1987, Crocker-Bedford and Chaney 1988, Hargis et al. 1994). On the TNF, goshawks selected nest sites in mature forest stands on north and west-facing aspects that had greater basal area, taller trees, more trees in the 38.0-45.5 centimeter dbh size class, and more space beneath the canopy compared to available habitat (Table 22). Squires and Ruggiero (1996) found many of the same structural variables to be significant in their study of goshawk nest site selection in south central Wyoming. Forest cover types in their study area included lodgepole pine with scattered aspen at lower elevations, and Engelmann spruce and subalpine fir at higher elevations. All nests were found in the lower elevation forest. Nest trees were significantly larger (height and dbh) than random plot center trees. Nest plots (0.04 ha circles) had greater basal area, greater density of large trees (22.6-40.4 cm dbh), greater height to live canopy, and greater average tree height compared to random plots (Squires and Ruggiero 1996). As on the TNF, they did not find a significant difference in canopy cover which averaged 67% at nest sites and 60% at random sites.

Many of the significant structural differences measured in nest plots in south central Wyoming also distinguished nest stands (groups of trees with homogeneous forest structure 0.4-13.0 ha in size): higher density of large trees, taller trees, and greater height to live canopy. Random stands had a significantly higher density of small trees (6.4-12.5 cm dbh) (Squires and Ruggiero 1996).

Results from these two habitat selection studies and the previous section show that patterns of goshawk nest site selection in the Rocky Mountain region are consistent even in different forest cover types. Taller and larger trees distinguish nest sites and stands from available habitat. Habitat selection studies from other areas in the United States have also found that goshawks place their nests in forests that contain a higher density of large mature trees and greater basal area (Hall 1984, Speiser and Bosakowski 1987, Hargis et al. 1994). These characteristics most likely reflect selection for nest stands that provide nesting platforms of adequate size, protection from predators and weather, and room for adult goshawks to maneuver beneath the canopy. Absolute values of habitat characteristics differ, however, depending upon the specific forest cover type where nests are located. I found significant differences in tree size, canopy cover, basal area and size class distribution of live trees between nest sites located in the two predominant forest cover types on the TNF: Douglas fir and lodgepole pine (Tables 12-16).

Nest clusters

Early research on goshawk nesting habitat focused on describing a small activity area (4-10 ha) surrounding nests occupied by goshawks in a given year (Reynolds et al 1982, Bartelt 1974). Delineation of the "nest site" or "nesting territory" in these early studies was based on observations of unmarked adults and fledged young as well as locations of plucking and roost sites (Reynolds 1983), or on the distance around the nest defended by the female adult goshawk (Bartelt 1974). Even though the existence of alternate nests was acknowledged, the combined area containing all alternate nests in a territory was not considered for analysis. Stands (defined as groups of trees with unique vegetative characteristics) in which nest trees were found have also been described by researchers (Reynolds et al 1982, Hall 1984, Kennedy 1988, Squires and Ruggiero 1996) but usually without reference to the matrix of vegetation surrounding such stands. Although of some value and interest, the drawback of stand analysis is the implication that goshawks prefer or select 8-12 hectare stands in which to place their nests (see Hejl et al. 1995 for an example of this). If habitat selection was occurring for larger patch sizes, it could not be determined from such an approach.

Data collected over a multi-year period at different study areas show that goshawks use a number of alternate nest sites within a territory and these sites can range from less than 100 m to over two kilometers apart (Reynolds et al. 1994, Woodbridge and Detrich 1994). The mean distance measured between alternate nests occupied in consecutive years in different parts of the western United States was quite consistent: 285 m on the TNF (n=24), 272 m in northern California (n=65) (Woodbridge and Detrich 1994), and 266 m in northern Arizona (n=17) (Reynolds et al, 1994). This suggests that the use of widely spaced alternate nests is not a response to local conditions, and that goshawks most likely select nesting areas that can provide a number of potential nest sites.

Woodbridge and Detrich (1994) found a relationship between patch size and occupancy rates of goshawk territories. They reported that for nest stand clusters greater than 61 ha, occupancy of territories was nearly 100% over a five year period compared to less than 50% occupancy at clusters <20 ha (Woodbridge and Detrich 1994). These data strongly support the idea that patch size plays a role in goshawk selection of nest areas.

I did not attempt to measure patch size of nest sites on the TNF due to the difficulty of defining what constitutes a patch in complex forest environments. At traditional territories on the TNF that contained more than one nest tree, the average distance between the most widely spaced nest trees within a cluster equaled 498 m $\pm$ 298 m (Table 6). The area of a circle with a radius this length equals 78 ha, which is nearly identical to the size of the NA analyzed in this study (81 ha). Data collected on mature forest cover within predetermined analysis areas in the territory core (NA and PFA), though not a direct measure of patch size, suggest that patch size is a component of goshawk nest site selection. The proportion of mature forest cover was greatest within the NA and PFA respectively, and averaged over 60% (Table 21, Fig. 10). In addition, comparison of high and low occupancy territories (Table 26) showed that high occupancy territories had significantly greater proportions of mature forest cover within 243 ha surrounding known nests (NA and PFA). To determine selection for patch size, a comparison of habitat within a series of concentric circular plots surrounding nest and random points would need to be made. In a similar study of spotted owl nesting habitat in northwestern California, there was a significantly greater amount of mature forest, and less fragmentation of forest cover up to 1200 m surrounding nest sites compared to random sites (Hunter et al. 1995).

Ephemeral territories

The total number of alternate nest trees at current territories on the TNF averaged 3.0 (81 trees/27 territories); however, at 26% (7/27) of the territories, I found only one nest tree. At four of these territories (D1-09, D2-05, D2-06, D2-07), searches for alternate nests were completed in a 1.6 kilometer radius of known nest sites but no additional nests were found. These territories, all in post-harvest areas of the TNF, appear to be ephemeral territories as defined by Woodbridge and Detrich (1994). In contrast to traditional nesting territories, where known nest clusters were occupied predictably by goshawks, ephemeral territories were occupied less frequently and nest sites were highly dispersed (Woodbridge and Detrich 1994). In northern California, these types of territories were associated with fragmented areas of lodgepole pine as were those found on the TNF (Woodbridge and Detrich 1994).

Newton has suggested that the continued use of particular nest sites over a number of years indicates their superiority to other potential local nesting areas (Newton 1976). Since all sites are not equal, competition for superior nest sites probably occurs. Poor or marginal territories may be suitable for nesting only in particular years or by certain birds (Newton 1991). It is likely that the single-nest, ephemeral territories represent marginal nesting habitat. While such sites might be considered by some to indicate a wide ecological tolerance by the goshawk, data from the TNF and northern California show that they represent exceptional situations compared to the majority of territories. Low occupancy rates suggest that these territories may represent sinks for surplus birds produced at other, source territories (Pulliam 1988).

Summary of habitat analyses within estimated home range areas

Overall, home range areas composed of less than 50% mature forest cover were the exception, not the norm. Mature forest cover predominated within the nest area, post-fledgling family area, and the foraging area at the majority of current nesting territories analyzed. Moving out from the core area towards the periphery of the home range, the proportion of mature forest decreased (Fig 10), and more area was covered by sage/shrub and open habitat (Douglas fir/mixed conifer territories) or seedling/sapling and young forest cover (lodgepole pine territories). Differences in the amount of mature forest cover, however, were not statistically significant among the three analysis areas (Table 21). Although I did not compare known home range areas to random locations on the forest, home range data by themselves suggest the importance of extensive mature forest habitat for nesting goshawks on the TNF.

At each analysis level, a few territories located in timber sale areas had a much lower portion of mature forest cover compared to mean values. Minimum values for mature forest cover measured at each analysis level were 24% in the NA (D3-06), 16% in the PFA (D2-07) and 34% in the FA (D2-07). Three minimally forested territories that contained less than 40% mature forest cover within either the NA, PFA, or FA (D2-06, D2-07, D3-06) appear to be ephemeral territories as only one active nest was found in one year of the study (Table 5). While high quality territories would be expected to be occupied in most years, poor territories may be suitable only in certain years or by certain birds (Newton 1991).

Differences in the proportion of mature forest cover between the FA and the two smaller analysis areas were somewhat obscured because I did not classify portions of the FA that fell outside of the Forest Service boundary. Most of these unclassified lands were probably not forested or had only scattered trees, so inclusion of these privately owned lands in the analysis would have lowered the average proportion of mature forest cover within the FA to some degree. Inclusion of these lands in the analysis probably would have resulted in a significant difference in proportion of mature forest cover between the NA and the FA, and perhaps the PFA and FA as well.

It is likely that stand characteristics of mature forest habitat such as average tree density, tree size, and canopy cover differed between the three analysis areas but I could not distinguish such differences given the limitations of the GIS database (Hunter et al. 1995). However, studies of habitat use by radio-tagged adult goshawks in the nesting season have shown a consistent preference by goshawks for closed canopy, mature/old growth forest stands for foraging as well as nesting, although other available age classes/canopy closure classes of forests are used for foraging as well (Fischer 1986, Austin 1993, Bright-Smith and Mannan 1994, Hargis et al. 1994). Hargis et al. (1994) specifically compared nest sites in eastern California to foraging and roosting locations of adults (determined by telemetry), and to random locations. They found that forest stands at both nest sites and foraging and roosting locations were distinguished from random locations by higher basal area, more canopy cover, and higher tree density in the 15-27 centimeter dbh and >46 cm dbh size classes. Further refinements in the GIS database on the TNF or extensive field sampling would be needed to distinguish what, if any, characteristics of mature forest stands differed between the FA, and the NA and PFA.

The only significant difference in proportion of cover types that distinguished the larger foraging area from both the NA and PFA, percent of sage/shrub habitat, suggests the value of this particular cover type for goshawk foraging habitat (Shuster 1980). Not all territories included this cover type, however. Six territories had less than 1.5% of sage/shrub cover within the estimated foraging area (Appendix K). This could be interpreted that sage/shrub cover is not always a distinguishing characteristic of foraging areas or that goshawks in these particular territories travel greater distances to utilize such habitat. The territories lacking this cover type were lodgepole pine territories located within or just south of the Island Park area. Lodgepole pine territories on the TNF had lower mean productivity compared to Douglas fir/mixed conifer territories (Appendix L). Observations of prey deliveries to nests, showed a significant difference between the proportion of mammal and bird prey items brought to Douglas fir and lodgepole pine nests (contingency test for proportions, $Z=3.314$, $p<0.05$) (Patla and Trost 1995b). Mammals comprised 76% (range 43-85%) of prey items ($n=64$) at Douglas fir nests compared to an average of 42% (range 28-57%, $n=40$) at lodgepole pine nests. Analysis of prey use at a larger number of nests, and quantification of prey densities in different cover types are needed to determine if prey abundance and use really are different in these cover types. If differences exist, different management strategies may be needed to maintain adequate prey populations in Douglas fir and lodgepole pine dominated habitats on the TNF.

Although many studies have analyzed habitat directly at or surrounding goshawk nest sites, few studies have analyzed areas larger than nesting stands comparable to my analysis of spatial components of the home range area. These studies from different regions, although few in number, lend credence to my conclusion that forest cover types predominate within estimated PFA and FA areas. In southern Utah, Johansson et al. (1994) used a GIS database to analyze square 600 acre PFA's centered at known nest trees. The ten broad GIS vegetation community classes (forest cover types) used were not broken down by size class and so preclude direct comparison with my data set. Based on the average of 30 nest sites, only 18% of a PFA was nonforested; 39% consisted of high density ponderosa pine (*Pinus ponderosa*) or mixed conifer, 8% low density ponderosa pine/mixed conifer, and 17% aspen/conifer (Johansson et al. 1994). At two other study areas, cover types were determined for larger areas surrounding nest sites. Bartelt (1977) reported that within a 10.4 km^2 area (1040 ha) surrounding four nests in the Black Hills of South Dakota forest cover ranged from 75% to 98%. In northern California, Hall (1984) measured an average of 84% forest cover (conifer and hardwoods) within a 3.2 kilometer radius (estimated home range area of 3217 ha) at 10 nest sites. Fifty-eight percent of the forest habitat consisted of stands with 40% or greater canopy cover.

A detailed habitat analysis of home range areas in northern California based on positions of radio-tagged adults during the breeding season also measured a preponderance of forest habitat within areas used by goshawks (Austin 1993). Home ranges (n=9) were composed of 10% mature/old growth (canopy cover > 40%), 42% closed small sawtimber (canopy cover > 40%), 28% open small sawtimber, and 12% pole-sized trees (Austin 1993). This study area had a 100 year history of timber harvesting and was composed of greater than 50% forested land in young or sparsely forested habitats overall. The selection by goshawks for dense stands of larger trees occurred within entire their home range area, not just at nest sites.

Explanations why goshawks select older, closed canopy forests for foraging and roosting have included availability of prey (Kenward 1982, Reynolds et al. 1992), suitable foraging habitat due to open understories and perch sites (Kenward 1982, Widén 1994), and thermal and protective cover (Austin 1993). Kenward (1996) has also emphasized the need for adequate prey during the winter and competition from other raptor species as possible reasons why goshawks in North America nest mainly in continuous woodland.

Relation between productivity and nest site/plot habitat variables

Results of regression analysis suggest that the highest productivity nest sites consist of patches of well developed mature forest habitat near high quality foraging habitats that contain abundant and available prey species. Using regression analysis, I found that productivity (based on one nest randomly selected at 27 current territories) was related positively to nest plot basal area, and negatively with distance of nest site to forest edge. This relationship, though significant, did not appear to be of much predictive value, however (Fig. 12) The negative relation between productivity and distance to edge appeared to be especially weak. A cluster of territories that had high productivity and was located very near the forest edge (see Fig. 12, upper right corner) consisted of sites located close to abundant ground squirrel populations. High basal area and distance from edge are probably important factors for maintaining preferred microclimatic conditions at the nest and for protection from predators (Reynolds et al. 1982; Hall 1984; Speiser and Bosakowski 1987; Chen et al. 1993). In locations where prey species are especially abundant, distance to edge may be less important because predation pressures at the nest site may be less, and well fed adults may be better able to thermoregulate and protect nest sites from other predators.

Raptor habitat studies evaluating the relationship of reproductive success to nest site habitat features have shown mixed results. Studies on Red-shouldered Hawks (*Buteo lineatus*) (Morris et al. 1982, Moorman and Chaoman 1996) and Red-tailed Hawks (Smith 1994) found no relationship between nest site habitat variables and nest success. Moorman and Chapman (1996) found that successful Red-tailed Hawk nests were placed in shorter trees compared to successful nests. Dijak et al. (1990) found a difference in nest tree diameter between successful and unsuccessful nests for Red-shouldered Hawks. Hennessy (1978) reported that on the Cache NF in southern Idaho and northern Utah, goshawk nests located on the bottom of slopes or in high canopy cover areas produced greater number of young compared to nests on the top of slopes or those with little canopy cover.

Given the large number of factors that potentially influence raptor nesting success, including weather, prey abundance and availability, behavior, age of breeding birds, genetics, predation, and inter-specific competition (Newton 1979), the relationship between habitat features of the nest site per se and productivity may be often be minor and difficult to tease out. The relatively low range of the number of young produced per nest by most diurnal raptors may also not be large enough to make regression analysis a particulary useful tool for identifying habitat features important to nesting goshawks. Patterns of habitat selection most likely ensure that most birds choose nest sites with habitat characteristics adequate for producing at least some young (Morrison, Marcot, and Mannan 1992). Birds that attempt to use extremely inferior sites, probably fail in their efforts early in the nesting season and go undetected for the most part.

Relation between cover types within home range areas and reproductive success

Overall, results from regression analyses did not appear to have much predictive value (Fig. 13, 14, 15) but perhaps they can offer some insight in the value of different cover types for nesting goshawks. The relationship between both occupancy and productivity and sage/shrub cover suggest that this cover type may provide a more consistent source of available prey on a year-to-year basis than other cover types used for foraging by the goshawk. The fact that in regression analyses proportion of mature forest cover was not positively related to occupancy or productivity at any level, does not negate the importance of this cover type, but rather indicates the relative low variability and high values for mature forest cover at all spatial levels. The negative relationship between productivity and the proportion of mature forest within the NA (Fig. 13), may reflect the fact reported in the previous section that some of the highest productivity territories were found near the forest edge close to abundant ground squirrel populations.

Comparison of high and low occupancy territories indicated that high occupancy territories were characterized by significantly greater proportions of mature forest cover, and less young forest and seedling cover within the central portion of the home range (Table 26). There was also proportionateley less young forest within the entire FA (Table 26). The relation of young forest and seedling cover types with lower occupancy territories suggests that such cover types likely provide reduced opportunities for foraging and other activities associated with breeding territories.

Shuster (1980) in Colorado was the first to suggest the importance of sage habitat and associated ground squirrel populations for nesting goshawks in the Rocky Mountain Region. Prey analyses and observations of foraging goshawks on the TNF also indicated that ground squirrels may be one of the most importance prey species found in sage/shrub habitats. The negative relation on the TNF between occupancy and the amount of seedling cover within the home range areas may reflect avoidance of clearcut areas by the goshawk, increased competition by more open country raptors, or decreased prey abundance or prey availability due to the reduction of cover within these areas (Austin 1993, Kenward 1996). The negative relation between occupancy and young forest cover suggests that immature stands containing small diameter trees also do not provide valuable prey or cover resources for the goshawk.

Although this study includes data from a longer period of time than most graduate research projects, results on the relation between occupancy and cover types should be considered with some caution. The average number of years territories were monitored under current habitat conditions was 3.7 (Table 25). My study may have been too short in duration to measure goshawk response to recent habitat changes (Crocker-Bedford 1990), or to have located all possible alternate nest areas (Woodbridge and Detrich 1994). An additional confounding factor was that if some territories contained highly dispersed nest sites, active nests located outside of survey areas may have been missed resulting in artificially low occupancy rates for some territories (Woodbridge and Detrich 1994).

Effects of timber harvesting

Ideally, to analyze the effects of habitat modification on goshawk nesting success, controlled experiments at known nesting areas would be used to test the effects of different levels and configurations of timber harvesting within home range areas on goshawk occupancy and productivity. The complex coordination, large sample numbers, and long time frames required for such experiments make it highly unlikely they could ever be carried out on public land. Monitoring changes in habitat as well as patterns of goshawk nest success over time within home range areas, while not as informative as controlled experiments, can offer insights into how silvicultural practices modify nesting habitat over time and how goshawks or other forest raptors respond to habitat changes (Crocker-Bedford 1990, Thomas et al. 1990, Raphael et al. 1996).

My analyses of the effects of timber harvesting at specific territories showed that goshawk territories situated in active timber harvest areas underwent significant decreases in mature forest habitat within estimated home range areas. The reduction of mature forest cover was largest proportionally within the nest area, and least within the larger foraging area (Fig. 15). The large reduction in mature forest cover within the nest area occurred even though TNF prescriptions were applied to protect known nest trees at a number of territories. These results suggest that the selection process of units for timber harvesting keys into stands that compose the central portion of goshawk nesting territories.

Occupancy rates of pre-harvest nesting territories in my study area were higher than post-harvest territories but differences were not significant. Goshawks have relatively long life spans (Terres 1980) and tend to show fidelity to traditional nesting areas even after disturbances have taken place (Reynolds 1983, Crocker-Bedford 1990, this study). Since harvesting occurred fairly recently at some territories, lag effects may have obscured occupancy patterns. Looking only at post-harvest territories, territories with high occupancy rates had significantly more mature forest cover within the NA (Table 28). At territories where nest sites were protected by large buffers, occupancy rates remained high, at least in the short term (Table 27).

Given the far ranging movements and large home ranges of the goshawk, it is impossible to determine (without radio-tagging breeding adults) whether failure to find an occupied nest at a monitored territory represents a shift of a nest cluster beyond the area surveyed or a net loss of a breeding territory. My monitoring data were based on surveys ranging between 0.8 and 1.6 kilometer radius around known nest clusters. Nests located at farther distances would not have been found. Thus, I cannot estimate from this study the net effect on the breeding population due to habitat loss from timber harvesting.

The fact that I found no difference in productivity between territories in pre- and post-harvest areas (Table 27) may mean that rather than experiencing a progressive decline in productivity related to loss in suitable habitat, goshawks may simply quit using a nesting territory when a certain threshold of habitat loss occurs, i.e. when most suitable nest sites are lost or when prey populations decline beyond a certain level (Doyle and Smith 1994). It could also be possible that a pair might continue to occupy a traditional territory post-harvest, but once that pair is gone, other goshawks may fail to recognize the area as suitable for nesting. These marginal nesting sites, however, may be occupied occasionally by pairs that successfully produce a high number of young in good breeding years (years of high prey productivity). Such occurrences would mask correlations between productivity and habitat features.

Analysis of habitat at three historical territories where goshawks no longer nest supports the idea that a threshold effect may occur when a certain level of habitat loss has been exceeded. Averages of mature forest cover within the NA, PFA, and FA at these territories were substantially lower than averages measured at current occupied territories. Habitat selection studies have shown a consistent selection by goshawks for nest sites with taller trees, more basal area, and a higher density of large diameter trees compared to available habitat. Patch size is probably also important. If appropriate nesting stands are not available, goshawk may not choose to settle in a particular area.

Beyond the loss of actual nesting habitat, it is thought that reductions in prey populations or prey availability may be the most critical effect of timber harvesting on the goshawk (Reynolds et al. 1992, Kenward 1996). It is important to note that in the two study areas where goshawk populations have been monitored most extensively in timber harvest areas (Klamath NF, Northern California; Kaibab NF, Northern Arizona), the golden-mantled ground squirrel (*Spermophilus lateralis*) was a primary goshawk prey species (Boal and Mannan 1994) (Woodbridge and Detrich 1994). This medium sized mammal appears to respond favorably to open habitats; it has been suggested that increases in this prey species may offset losses of other prey species associated with mature forest habitat (Woodbridge and Detrich 1994).

On the TNF, a mid-sized mammal whose population is known to increase in response to post-harvest conditions is the northern pocket gopher (*Thomomys talpoides*) (Teipner et al. 1983). Goshawk prey analysis showed that the pocket gopher comprised only 1% of the biomass of total goshawk prey on the TNF (Table 9). Staying mostly underground, gophers are probably not often available for foraging goshawks. Gopher control programs in newly planted areas on the TNF also reduce numbers in areas where they may be most prolific (Barnes et al. 1985). Most of the important goshawk prey items identified on the TNF (based on biomass or number) except for ground squirrels are associated with forest habitat: snowshoe hare, Ruffed Grouse, Blue Grouse, red squirrel, and Northern Flicker (Reynolds et al. 1992). From what I could determine through visual inspections of clear cut areas and discussions with Forest Service personnel, ground squirrels do not appear to move into harvested units in any noticeable numbers on the TNF even when replanting efforts fail and such units remain open for extended periods of time. Even if prey populations do increase in clear-cut units, the lack of certain habitat features, such as perches or adequate cover, may preclude foraging in such areas by goshawks (Widén 1994). Also, after such units regenerate into densely spaced, even-aged stands, they likely provide little opportunity for foraging goshawks for decades.

The only study that attempted to measure effects of timber harvesting on goshawk reproduction occurred in ponderosa pine and mixed conifer habitat in Northern Arizona (Crocker-Bedford 1990). This study reported a substantial decrease both in occupancy and productivity in post-harvest territories in 1987 even if nest buffers up to 500 acres were retained around known nests. Reduction in prey populations, competition for nest sites by more open country raptors, and predation by Great Horned Owls were suggested as possible factors affecting goshawk reproductive success. Crocker-Bedford (1995) reanalyzed this data set to compare rates of goshawk occupancy and nestling production from 1987 to the amount of harvesting that had taken place between 1973 and 1986 within home range areas of 2290 ha (2.7 kilometer radius circular area) around the center of nest clusters. Both occupancy and productivity appeared to be inversely related to the amount of harvesting that had taken place within the home range area. Territories were grouped into four categories: 1) little or no harvesting (n=12); 2) 10-39% of home range harvested (n=14); 3) 40-69% harvested (n=16), and 4) 70-90% harvested. For these categories occupancy rates in 1987 were 83%, 43%, 31% and 9%, and productivity rates were 1.67, 0.86, 0.31 and 0.00 respectively (Crocker-Bedford 1995).

In comparison, on the TNF, I found no difference in mean productivity between pre- and post-harvest territories, and a smaller reduction in occupancy in the post-harvest group. The range of habitat loss within my study territories was much less than the range reported for the Kaibab territories, however, and harvesting methods differed as well. The amount of the home range (FA) harvested (clear cut type of harvests) ranged from 9-35% at current territories on the TNF (Appendix M) and from 39-53% at historical territories (Appendix N). Mean occupancy rates for current pre- and post-harvest territories on the TNF were very close to values reported for the undisturbed and 10-39% harvested group on the Kaibab: 79% and 47% on the TNF compared to 83% (undisturbed) and 43% (10-39% harvested territories) on the Kaibab NF. Given the data presented (Crocker-Bedford 1995), I could not determine whether differences reported in productivity and occupancy between the non-disturbed and the 10-39% harvested group of territories were statistically significant.

For the Northern Spotted Owl, Bart (1995) reported that number of young fledged per pair showed a linear relationship with the proportion of suitable habitat found surrounding the nest site. He did not find a threshold value above which there was little or no increase in productivity. Since goshawks, compared to the spotted owl, appear to have greater foraging flexibility, taking a greater variety of prey species, their response to loss of mature forest habitat may not be as sensitive or as incremental in nature. It is also possible that my data set may have had too few territories and too small a variation in proportion of mature forest cover within home range areas to detect a linear relationship between productivity and mature forest cover, even if one did exist. I also made the assumption that the GIS category "mature forest" represented suitable habitat for goshawks. This category, because it was defined only by tree size, may have actually contained an undetermined amount of habitat that was not suitable either for nesting or foraging, thus obscuring any relationship between productivity and cover type.

SUMMARY AND CONCLUSIONS

Goshawk nest sites on the TNF were located in areas of extensive mature forest habitat, primarily in Douglas fir cover types. I found no statistical difference in the proportion of mature forest cover within the defined nest area, post-fledgling family area and the overall foraging area. Mature forest cover averaged over 60% in all three analysis areas. Goshawks selected nest sites within home range areas that had greater basal area, taller trees, greater under canopy space, and higher density of trees in the 38.0-45.5 cm dbh size class. Nests also tended to be placed on north and western aspects in single species stands. Overall, nesting chronology, productivity and occupancy rates on the TNF were comparable to other goshawk study areas. Nesting territories contained a number of alternate nests (range 1-7). Eighty seven percent of alternate nests used within 1-2 years were located more than 100 m from the last nest used. Alternate goshawk nests provided an important source of nests for Great Gray Owls on the TNF: owls were found nesting in 30% of current goshawk territories. Distance between goshawk and Great Gray Owls nests within the same territories averaged 395 m.

Goshawk productivity was lower in years with wet, cold spring weather. Productivity was positively related to basal area of the nest site, amount of sage/shrub cover within the foraging area, and negatively related to distance to edge although these relationships accounted for only a small portion of the variation in number of young produced. Nest sites with a home range primarily in Douglas fir/mixed conifer habitat had higher mean productivity compared to sites in lodgepole pine habitat.

Occupancy of nesting territories was positively related to the amount of sage/shrub habitat within the post-fledgling family area and the overall foraging area. High occupancy territories had more mature forest cover within the nest area and post-fledgling family area, less seedling cover within the nest area and post-fledgling family area, and less young forest within all three analysis areas. These results suggest the importance of sage/shrub cover for providing consistent foraging opportunities. Seedling areas and young forests may have less prey or may be avoided by goshawks.

Clear-cut harvesting methods used on the TNF significantly reduced mature forest habitat at all three analysis areas surrounding nest sites in timber harvest areas but habitat loss was proportionately greatest within the central core area. In post-harvest territories, high occupancy sites had significantly greater amounts of mature forest cover left within the nest area. It appears from data on the TNF and other locations that goshawks show quite consistent patterns of nest site selection. Even in post-harvest areas, they place their nests, for the most part, in remaining untreated forest patches (Woodbridge and Detrich 1994). In areas on the TNF that have undergone repeated harvesting, the lack of suitable remaining patches and/or lack of suitable prey may preclude nesting by the goshawk.

MANAGEMENT IMPLICATIONS

Habitat analysis of goshawk nest sites and surrounding home range areas on the TNF illustrates why goshawk nesting habitat may be particularly vulnerable to timber harvesting. Silviculturists selecting high volume stands to meet harvest objectives are likely to select similar stands to those selected by goshawks for nesting: older stands with high basal area and large trees on moderate slopes in lower elevation areas. While the removal of some proportion of mature forest cover may not be detrimental to nesting goshawks, as indicated by the proportion of study territories on the TNF that contained areas of seedling/treated stands, repeated harvesting within management areas over time may effectively remove most mature stands that have suitable structure for nesting and foraging.

To counter balance the incremental and continued loss of suitable habitat over time, land managers need to plan on a Forest-wide scale. Goshawk habitat management guidelines should include protection of core areas and high quality foraging habitat in traditional nesting territories, extended rotation times for treatment of individual stands throughout the TNF, conservation of intact patches of productive lower elevation mature and old growth forests, and managing younger stands in disturbed areas to create future goshawk habitat (Lilieholm et al. 1994, Dewhurst et al. 1995). Managing habitat for goshawk nesting territories on a landscape scale across the entire TNF could provide habitat for a variety of forest dependent species including the Great Gray Owl as well as the goshawk (Harris 1984, Robinson 1988)

Management recommendations for the Northern Goshawk have been developed for the southwestern United States (Reynolds et al. 1992). Within the PFA and FA, the MRNG recommendations for retention of 60% cover in mid-aged, mature and old forest stands (20% in each category) were very close to the average proportion of total mature forest cover found within estimated goshawk PFA's and FA's on the TNF. Given the limitations of the GIS data base, I could not break out percentages of mid-aged, mature and old forest based on diameter as done in the MRNG (see MRNG Appendix 4, Table 3), but these size categories combined correspond to the TNF mature category.

Even though my analysis seems to support the recommended levels of mature forest habitat to be retained for nesting goshawks in the SW plan, I suggest that application of the MRNG guidelines should proceed cautiously and be monitored closely for three reasons. First, levels of mature forest cover in goshawk territories in undisturbed areas on the TNF (n=11) averaged higher than the recommended levels (NA= 83%, PFA=77%, FA=68%) (Table 34). Intensive monitoring and prey studies of nesting pairs in undisturbed habitat could help us gain understanding why goshawks nest in such extensively forested habitat, and what specific habitat features are most important for reproductive success and survival. Second, it is important to remember that the averages I calculated for mature forest cover at different spatial levels represent a mixture of territories: some in highly disturbed areas and others in less disturbed areas of the TNF. Due to possible lag effects in goshawk response, it is still not clear if goshawks will continue to use all the disturbed territories. The amount of actual harvesting that may impact goshawk nesting efforts will depend ultimately on the quality of habitat that remains. While the 60% guideline may be adequate in some areas of the forest, in others it may be less than required. Third, these guidelines were written for southwestern forests where selection, uneven aged harvesting methods are used. Clear cut harvesting creates an entirely different landscape so proportions of mature habitat needed to support breeding goshawks may be quite different over time as well.

Further research is needed to collect more precise information on how goshawks are using habitat within their home ranges. If we could understand what makes certain habitat features valuable for nesting and foraging goshawks, these features could be preserved in disturbed areas to mitigate adverse effects and perhaps retain goshawks even in more highly disturbed areas of the forest (Widén 1994). As aptly stated by Widén (1994): ". . .raptor habitat conservation is a matter of finding why certain habitats are preferred, what factors make them valuable, as well as how depleted habitats can be improved." Radio-tracking studies of breeding pairs throughout the entire year incorporating ground and aerial observations are needed to collect precise data on habitat use and habitat features most important for goshawks in undisturbed and timber harvest areas. Combined with continued monitoring of known nest areas, such studies would help ensure that a well distributed and viable population of breeding goshawks persists.

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TABLE 1. List of five categories used for analysis of cover types within goshawk home range areas. Shown are ARC/INFO GIS vegetation classes included in each category. See Appendix B for definitions of Targhee National Forest GIS classes.

	TNF GIS Vegetation Class	
Goshawk Habitat Analysis Category	Attribute Symbol	Tree Size Class
Mature Forest	DF, LP, MX, MX3 AS, SF, WB, NDF NMX, NAS	9
Young Forest	DF, LP, MX, MX3 AS, SF, NDF, NMX	8
Seedling/sapling/cut	DF, LP, MX, MX3 AS, SF, NDF, NMX	5,6,7
	1DF, 1LP, 1MX	9 (or no size class)
Sage/shrub	M, MB, TSG, W	
Open Area	GR, GRB, GRS, GRF, WA, R	

TABLE 2. List of goshawk study territories, Targhee NF. Status indicates time period territory was occupied by goshawks. Forest type refers to dominant conifer species within home range area. Key to codes: STATUS–C current, H historical, H/C historical current; FOREST TYPE–DF Douglas fir, LP lodgepole pine, MX mix of DF and LP; METHOD OF DISCOVERY–CE chance encounter, TS timber sale associated activitiy, BS broadcast survey.

	Territory #	Location	Status	Forest Type	Year First Found Active	Year Timber Harvest In Area	Method Of Discovery
1	D1-02	Medicine Lodge	C	DF	1989	none	CE
2	D1-03	Medicine Lodge	H/C	DF	1983	none	CE
3	D1-04	Centennial Mts.	H/C	DF	1984	1991	TS
4	D1-06	Centennial Mts.	H/C	DF	1985	1971-79	CE
5	D1-08	Centennial Mts.	C	DF	1990N	1970-1985	BS
6	D1-09	Centennial Mts.	H/C	DF	1983	1987	TS
7	D1-10	Centennial Mts.	C	DF	1988	1989	TS
8	D1-11	Centennial Mts.	C	DF	1990	1989-91	TS
9	D1-12	Centennial Mts.	C	DF	1993	none	BS
10	D1-13	Centennial Mts.	C	DF	1993	none	BS
11	D2-01	Centennial Mts.	C	DF	1989	none	BS
12	D2-02	Centennial Mts.	C	DF	1988N	1989-92	TS
13	D2-03	Centennial Mts.	C	DF	1990	none	BS
14	D2-04	Henry's Lake Mts.	C	MX	1990	none	CE
15	D2-05	Island Park area	C	LP	1991	1990	CE
16	D2-06	Island Park area	C	LP	1992	1960-1990's	TS
17	D2-07	Island Park area	C	LP	1992	1960-1990's	TS
18	D3-01	Island Park area	C	LP	1990	1987	BS
19	D3-02	Island Park area	H	LP	1981	1978,81	CE
20	D3-04	Island Park area	H	LP	1985	1985	TS
21	D3-06	Fall River area	C	MX	1989	1976-78	CE
22	D3-07	Teton Front area	C	LP	1989	none	TS
23	D4-01	Big Hole Mts.	H/C	LP	1986	1989-90	TS
24	D4-04	Snake River Range	H/C	DF	1985N	none	TS
25	D5-01	Teton Front area	H	MX	1980	1985-86	TS
26	D5-03	Big Hole Mts.	H/C	MX	1987	1985-86	TS
27	D5-05	Big Hole Mts.	H	MX	1981	1986-87	TS
28	D5-07	Big Hole Mts.	H/C	MX	1987	1991	TS
29	D5-09	Big Hole Mts.	C	MX	1990	1991	TS
30	D5-10	Big Hole Mts.	C	MX	1991	none	CE
31	D5-11	Big Hole Mts.	C	MX	1992	none	CE

TABLE 3. Goshawk productivity data for territories monitored, 1989-1994, on the Targhee NF. See Methods Section for definition of terms.

	1989	1990	1991	1992	1993	1994	TOTAL	MEAN	SD
Number of breeding pairs	8	9	12	20	11	8	68	11	4.5
Total # of young produced	14	20	19	42	16	21	132	22	10.1
# young produced/breeding pair	1.75	2.22	1.58	2.10	1.45	2.63		1.96	0.44
# young produced/successful nest	2.00	2.22	1.90	2.33	1.6	2.63		2.11	0.36
Percent of nests produced 1 young	38%	11%	17%	16%	45%	0%		21%	17%
Percent of nests produced 3 or 4 young	38%	33%	8%	32%	6%	63%		30%	21%
# of nests that failed	1	0	2	2	1	0	6	1.0	0.9
Percent of nests that failed	13%	0%	17%	10%	9%	0%		9%	7%

TABLE 4. Weather data variables used to analyze the relationship between weather and goshawk reproductive success, 1989-1994. Mean temperature and precipitation data from Driggs, ID (St. #2676, Teton County, elevat. 1866 m). Snow data from Pine Creek Pass (Station #6720, Teton County, elevat. 2049 m).

Year	#Young Goshawks Per Nest	Occup Surveys A & B	March Snow depth (cm)	March SWE (%)	Mean March Temp (C)	Mean April Temp (C)	Mean May Temp (C)	Total March Precip (cm)	Total April Precip (cm)	Total MAY Precip (cm)	Mean Mar+Ap Temp (C)	Total Mar+Ap Precip (cm)	Mean Ap+May Temp (C)	Total Ap+May Precip (cm)
1989	2.00		145	41	0.6	5.6	9.4	6.5	1.1	4.5	6	7.6	15.0	5.6
1990	2.22	0.71	61	23	0.6	6.7	8.3	0.9	4.9	3.8	7	5.9	15.0	8.7
1991	1.90	0.79	104	25	0.0	3.3	7.8	3.3	4.0	9.5	3	7.3	11.1	13.5
1992	2.28	0.81	58	22	3.3	7.2	11.7	2.5	1.9	2.3	11	4.4	18.9	4.2
1993	1.60	0.45	102	36	-2.2	1.7	9.4	2.2	6.2	7.5	-1	8.4	11.1	13.7
1994	2.63	0.42	92	32	0.6	5.5	11.1	0.2	2.4	2.6	6	2.6	16.6	5.0
30 year mean (1961-1990):					-2	4	9	2.8	3.3	5.1				

TABLE 5. Summary of number and status of nest trees found at goshawk study territories, 1989-1994, Targhee NF. Active nests were nests where goshawk use was documented at least once during the time span indicated. Lost nest trees were active or alternate trees that were either harvested, blown down, or died.

Territory ID	# Active Nest Trees Current 1988-1994	# Active Nest Trees Historical 1980-1987	#Alternate Nest Trees Current 1988-1994	#Alternate Nest Trees Historical 1980-1987	TOTAL Nest Trees	#NEST TREES LOST
D1-02	2		1		3	1
D1-03	1				1	
D1-04	3	1			4	1
D1-06	4		3		7	
D1-08	3		2		5	1
D1-09	1				1	1
D1-10	4		1		5	
D1-11	2		2		4	2
D1-12	1		4		5	
D1-13	1		1		2	
D2-01	2		2		4	
D2-02	2		1		3	
D2-03	1		1		2	
D2-04	3		2		5	
D2-05	1				1	
D2-06	1				1	
D2-07	1				1	
D3-01	2				2	
D3-02				1	1	
D3-04		1			1	1
D3-06	1				1	
D3-07	1				1	
D4-01	2				2	
D4-04	2			1	3	
D5-01		2	1		3	2
D5-03	2		1		3	
D5-05		3			3	1
D5-07	3		1		4	
D5-09	5				5	
D5-10	3				3	
D5-11	3				3	
TOTALS:	57	7	23	2	89	10

Table 6. *Summary of the greatest distance measured between alternate nests in nest clusters that contained more than one nest,* Targhee NF, 1989-1994.

Territory ID	Number of nests per territory	Distance between farthest nests (m)
D1-02	3	124
D1-04	4	713
D1-06	7	1163
D1-08	5	419
D1-10	5	1073
D1-11	4	570
D1-12	5	454
D1-13	2	444
D2-01	4	384
D2-02	3	524
D2-03	2	107
D2-04	5	752
D3-01	2	170
D4-01	2	104
D4-04	3	245
D5-03	3	785
D5-07	4	695
D5-09	5	457
D5-10	3	344
D5-11	3	425
MEAN	3.7	498
SD	1.3	298
SE		67
n		20

TABLE 7. Monitoring results for 76 goshawk nest trees, 1989-1994, Targhee NF. Shown are the total number of nests rechecked per year. Other raptor species found using goshawk nests included great gray owl, long-eared owl, great horned owl, and Cooper's Hawk.

	1989	1990	1991	1992	1993	1994	TOTAL
Number of nests checked							
All nests	5	23	30	40	59	72	229
Number reused by goshawks							
All nests	1	1	4	5	4	3	18
Percent reused by goshawks							
All nests	20%	4%	13%	13%	7%	4%	8%
Number used by other raptors							
All nests	0	4	3	8	7	7	29
Percent used by other raptors							
All nests	0%	17%	10%	20%	12%	10%	13%

TABLE 8. Summary of monitoring results at known goshawk territories on the Targhee NF, 1990-1994. Results have been calculated two ways: based on all territoires surveyed at Levels A, B and C, and based on territories surveyed at Levels A and B only. Year of discovery was not included in the total of years monitored. See Methods for definition of terms and survey levels.

	Monitoring Years						
	1990	1991	1992	1993	1994	Total	
ALL SURVEY LEVELS							
Number of territory year-checks	15	24	26	29	29	123	
Number occupied	5	11	17	10	8	51	(41%)
(percent)	(33%)	(46%)	(65%)	(34%)	(28%)		
Number not occupied	10	13	9	19	21	72	(58%)
SURVEY LEVELS A and B ONLY							
Number of territories monitored	7	14	21	22	19	83	
Number occupied	5	11	17	10	8	51	(61%)
(percent)	(71%)	(79%)	(81%)	(45%)	(42%)		
Number not occupied	2	3	4	12	11	32	(39%)

TABLE 9. Goshawk prey species, Targhee NF, 1989-1993. See Appendix G for scientific names and weights used to calculate biomass.

COMMON NAME	Number of Prey Items: PELLETS or PREY REMAINS	BLIND OBSERVATIONS	Sub-total Birds or Mammals		Percent of Total Biomass
	n	n	n	%	%
BIRDS					
Ruffed Grouse	16		16	18.8%	13.3%
Blue Grouse	5		5	5.9%	7.5%
Grouse, sp.		6	6	7.1%	7.0%
Bird (medium), unidentifed	5	21	26	30.6%	3.8%
Common Raven	2		2	2.4%	2.5%
Nothern Flicker	7	1	8	9.4%	1.6%
Cooper's Hawk	3		3	3.5%	1.9%
Long-eared Owl	2		2	2.4%	0.8%
Boreal Owl	1		1	1.2%	0.5%
American Robin	2	2	4	4.7%	0.5%
Clark's Nutcracker	1	1	2	2.4%	0.4%
Duckling, sp.		2	2	2.4%	0.3%
Steller's Jay	2		2	2.4%	0.3%
Gray Jay		1	1	1.2%	0.1%
Woodpecker, sp.		1	1	1.2%	0.1%
Red-naped Sapsucker	1		1	1.2%	0.1%
Townsend's Solitaire	1	1	2	2.4%	0.1%
Williamson's Sapsucker	1		1	1.2%	0.1%
TOTAL BIRDS	49	36	85	100.0%	41%
MAMMALS					
Snowshoe Hare	11	2	13	12.9%	30.0%
Unita Ground squirrel	1	41	42	41.6%	14.9%
Red Squirrel	14	4	18	17.8%	5.1%
Medium mammal, unidentified		10	10	9.9%	3.2%
Marmot	1		1	1.0%	2.6%
Nuttall's Cottontail	2		2	2.0%	1.4%
Pocket Gopher	5		5	5.0%	0.9%
Long-tailed Weasel	2		2	2.0%	0.5%
Vole,sp.	4		4	4.0%	0.2%
Northern Flying Squirrel	1		1	1.0%	0.2%
Yellow Pine Chipmunk	1		1	1.0%	0.1%
Small rodent, unidentified	2		2	2.0%	0.1%
TOTAL MAMMALS	44	57	101	100.0%	59%
TOTAL NUMBER : all prey items	93	93	186		
PERCENT BIRDS	52.7%	38.7%	45.7%		
PERCENT MAMMMALS	47.3%	61.3%	54.3%		

TABLE 10. Species of nest trees used by goshawks, 1989-1993, classifed by canopy position and topographic position.

	NEST TREE SPECIES					
	Douglas Fir	Lodgepole Pine	Aspen	Engelmann Spruce	TOTAL	PERCENT
TOTAL NUMBER OF NEST TREES: (percent)	38 (78%)	9 (18%)	1 (2%)	1 (2%)	49	
CANOPY POSITION						
Dominant	7				7	14%
Codominant	30	7	1	1	39	80%
Intermediate		1			1	2%
Supressed snag (shaded)	1				1	2%
Snag (no canopy cover)		1			1	2%
TOPOGRAPHIC POSITION						
Upper	4				4	8%
Middle	20	2			22	45%
Lower	11	1	1	1	14	29%
Flat	3	6			9	18%

TABLE 11. Type of nest structures of goshawk nests occupied 1989-1993 , Targhee NF. (n=49). See text for description of types. Also shown is the number of nests with support branches deformed by mistletoe infections.

	NEST TREE SPECIES					
NEST STRUCTURAL TYPES	Douglas fir	Lodgepole Pine	Aspen	Engelmann Spruce	TOTAL	PERCENT
Platform	15	2		1	18	37%
Basket	11	1			12	24%
Broom	7	4			11	22%
Broken Crown	5	2	1		8	16%
NESTS WITH MISTLETOE	10	3			13	27%

TABLE 12. Comparison of Level 1 habitat characteristics for all active goshawk nests found 1989-1993, TNF. Shown are values calculated for all nests (n=49) ,and for only one nest per territory (n=27) at DF and LP territories. Probability values indicate results of a statistical comparison (MRPP) of Douglas fir and lodgepole pine nest sites.

Variable		All Nests (n=49)		Douglas Fir (n=21)		Lodgepole Pine (n=6)		p-value
		mean	SE	mean	SE	mean	SE	
		(range)		(range)		(range)		
Nest tree height (m)		25	1	27	1	20	2	0.004
		(12-38)		(12-38)		(16-26)		
Nest tree dbh (cm)		43.6	2.5	48.3	3.5	24.5	1.8	0.001
		(16.3-84.1)		(20.8-84.1)		(21.6-33.0)		
Nest height (m)		13	0.4	14	0.7	13	1	0.544
		(7-21)		(8-21)		(11-17)		
Nest Ht /Tree Ht (%)		0.53	0.02	0.53	0.03	0.68	0.03	0.006
		(0.29-1.00)		(0.29-1.00)		(0.60-0.79)		
Nest tree canopy cover (%)	(a)	79	3	85	2	54	7	0.000
		(29-96)		(72-96)		(29-70)		
Nest tree age (years)	(b)	131	9	143	13	96	8	0.052
		(62-280)		(62-280)		(72-113)		
Elevation (m)		2119	16	2147	25	1994	40	0.004
		(1860-2415)		(1860-2415)		(1890-2165)		
Percent slope (%)		22	2	26	3	13	4	0.027
		(0-47)		(5-47)		(3-27)		

(a) n= 41 (all nests) n = 18 (DF)
(b) n= 43 (all nests) n = 20 (DF) n = 5 (LP)

TABLE 13. Distances (mean, standard error and median) from goshawk nest clusters to forest edge, permanent water and roads on the TNF, 1989-1993. Probability values indicate results of a statistical comparison (MRPP) of Douglas fir and lodgepole pine territories.

Variable	All Territories (n=27)			Douglas fir nests (n=21)			Lodgepole Pine nests (n=6)			p-value
	mean	median (range)	SE	mean	median (range)	SE	mean	median (range)	SE	
Distance to forest edge (m)	299	122 (11-1610)	75	307	122 (11-1610)	90	272	137 (30-793)	126	0.973
Distance to permanent water (m)	552	343 (30-2706)	116	443	333 (30-1753)	93	934	648 (152-2706)	395	0.352
Distance to open road (m)	1186	1290 (114-4573)	170	1290	1094 (114-4573)	209	824	893 (84-1372)	184	0.349

TABLE 14. Comparison of Level 2 nest stand characteristics at goshawk nests found 1989-1993, TNF. Values are given for all plots measured and also for one randomly selected nest per territory per cover type (DF or LP). Probability values (MRPP) reflect comparisons between Douglas fir and lodgepole pine nest stands. Plot size used was a 66 ft radius circle centered at the nest tree (area=0.314 acre).

Variable	All Plots (n=44) mean	SE	Douglas Fir (one plot/territory) (n=20) mean	SE	Lodgepole Pine (one plot/territory) (n=7) mean	SE	p-value
	(range)		(range)		(range)		
Mean sawtimber DBH (cm)	30.8	1.0	34.0	1.2	22.9	0.8	0.000
trees > 17.8 cm	(20.3-47.0)		(24.0-43.6)		(20.3-25.5)		
Density sawtimber (trees/ha)	383	21	381	30	335	35	0.423
trees > 17.8 cm	(134-717)		(134-717)		(252-520)		
Basal area (m^2/ha)	27.7	1.5	32.6	1.8	14.1	2.2	0.000
trees > 17.8 cm	(8.7-51.2)		(20.0-51.2)		(8.7-26.3)		
Mean snag DBH (cm)	15.1	0.9	15.5	1.7	15.7	1.1	0.154
snags > 2.5 cm	(9.0-38.1)		(9.4-38.1)		(12.3-19.5)		
Density snags (snags/ha)	286	32	297	54	355	7	0.453
snags > 2.5 cm	(24-827)		(24-803)		(134-685)		
Stand canopy cover (%)	(a) 73	3	80	2	50	8	0.000
	(27-94)		(60-94)		(27-84)		

(a) n= 40 (all stands) n=19 (DF stands)

TABLE 15. Comparison of density of live trees in different size câtegories in nest stands at DF and LP goshawk territories, 1989-1993, TNF. Probability values indicate results of MRPP tests for paired comparisons. Plot size used was a 66 ft radius circle (area=0.314 ac) meaured at one nest site randomly selected per territory.

VARIABLE		Dougals fir (n=20) mean	SE	(range)	Lodgepole Pine (n=7) mean	SE	(range)	p-value
TREE DENSITY (trees/ha):								
Large sawtimber (> 40.6 cm dbh)		82	11	(0-181)	2	4	(0-8)	0.000
Medium sawtimber (30.5-40.6 cm)		108	13	(24-283)	16	10	(0-63)	0.000
Small sawtimber (17.8-30.5 cm dbh)		192	32	(16-614)	318	28	(213-449)	0.010
Pole sized timber (7.6-17.8 cm)		127	22	(8-378)	321	110	(47-874)	0.054
Saplings (3.8-7.6 cm)		67	20	(0-283)	474	133	(0-1126)	0.000
Seedlings (< 3.8 cm dbh)	(a)	363	123	(0-1693)	1672	823	(126-6488)	0.015
GROUND COVER HEIGHT (cm)	(b)	19	2	(1-33)	25	2	(17-32)	0.200
MATURE DOWNFALL (number/ha) downed logs > 17.8 cm dbh	(c)	14	3	(1-44)	134	44	(20-252)	0.000

(a) n=18 (DF)
(b) n=18 (DF), n=6 (LP)
(c) n=17 (DF), n=5 (LP)

TABLE 16. Comparison of snag density of different size categories in nest stands at DF and LP goshawk territories 1989-1993, TNF. Probability values indicate results of MRPP statistical analysis. Plot size used was a 66 ft radius circle (area=0.314 ac) measured at one randomly selected nest site per territory.

VARIABLE	Douglas Fir (n=20)			Lodgepole Pine (n=7)			p-value
	mean	(range)	SE	mean	(range)	SE	
SNAG DENSITY (snags/ha)							
Large mature (> 40.6 cm dbh)	5	(0-47)	3	0	(0)	0	0.163
Medium mature (30.5-40.6 cm)	12	(0-55)	3	6	(0-31)	4	0.460
Small mature (17.8-30.5 cm dbh)	46	(0-244)	13	119	(16-362)	45	0.094
Pole-size (7.6-17.8 cm)	158	(0-472)	32	188	(31-386)	42	0.181
Sapling-size (3.8-7.6 cm)	76	(0-213)	19	30	(0-110)	15	0.123

TABLE 17. Proportions of different cover types within the nest area (81 ha) of goshawk territories, 1989-1993, TNF. Values are shown for all territories combined and for DF and LP territories separately. Probability values indicate results of MRPP test comparing DF and LP nest areas. Cover types were measured using ARC/INFO vegetation coverages from the TNF.

Cover Type	All Current Territories (n=27)		Douglas Fir Territories (n=20)		Lodgepole Pine Territories (n=7)		p-value
	mean (range)	SE	mean (range)	SE	mean (range)	SE	
Mature sawtimber (%)	68% (24-100%)	4%	72% (24-100%)	5%	57% (25-100%)	10%	0.193
Young sawtimber (%)	3% (0-35%)	1%	1% (0-15%)	1%	9% (0-35%)	5%	0.011
Seedlings (%)	20% (0-61%)	4%	15% (0-57%)	4%	33% (0-61%)	8%	0.062
Sage/shrub (%)	6% (0-49%)	2%	8% (0-49%)	3%	1% (0-5%)	1%	0.151
Open/grassland/rocks (%)	3% (0-20%)	1%	3% (0-20%)	1%	0% (0-2%)	0%	0.171

TABLE 18. Proportion of different cover types found within gosahwk territory PFA's calculated with and without inclusion of the central nest area (81 ha). Values were calculated for 27 goshawk territories between 1989 and 1993. Data compiled from ARC/INFO vegetation coverages from the Targhee NF.

Vegetation Class	PFA (243 ha) All Territories (n=27)		PFA (162 ha) All Territories (n=27)	
	mean (range)	SE	mean (range)	SE
Mature sawtimber (%)	66% (19-100%)	4%	66% (16-100%)	4%
Young sawtimber (%)	5% (0-26%)	2%	6% (0-29%)	2%
Seedlings (%)	18% (0-56%)	3%	17% (0-64%)	4%
Sage/shrub (%)	7% (0-37%)	2%	7% (0-34%)	2%
Open/grassland/rocks (%)	4% (0-34%)	1%	4% (0-43%)	2%

TABLE 19. Proportion of different cover types found within PFA's (162 ha) at goshawk territories 1989-1993, TNF. P values indicate results of MRPP analysis comparing DF and LP territories. Percent cover types were determined using ARC/INFO vegetation coverages.

Vegetation Class	DOUGLAS FIR (n=20) mean	SE	(range)	LODGEPOLE PINE (n=20) mean	SE	(range)	MRPP p-value
Mature sawtimber (%)	70%	3%	(48-100%)	52%	11%	(16-100%)	0.072
Young sawtimber (%)	3%	1%	(0-23%)	15%	4%	(0-29%)	0.005
Seedlings (%)	13%	3%	(0-47%)	31%	9%	(0-64%)	0.039
Sage/shrub (%)	9%	3%	(0-34%)	2%	2%	(0-13%)	0.152
Open/grassland/rocks (%)	6%	2%	(0-43%)	0%	0%	(0-1%)	0.055

TABLE 20. Proportions of different cover types found within the foraging area (2428 ha) at goshawk territories occupied 1989-1993, TNF. Values are shown for all territories combined, and for DF and LP territories separately. P values indicate results of MRPP test comparing DF and LP foraging areas. Percent cover types were determined using ARC/INFO vegetation coverages.

Area and Cover Type	Foraging Area All Territories (n=27)		Douglas Fir (n=20)		Lodgepole Pine (n=7)		MRPP p-value
	mean (range)	SE	mean (range)	SE	mean (range)	SE	
Area analyzed (ha)	2124 (1243-2416)	70	2067 (1243--2416)	84	2286 (1654-2416)	107	
Mature sawtimber (%)	61% (34-87%)	2%	62% (43-84%)	3%	58% (34-87%)	6%	0.794
Young sawtimber (%)	5% (0-38%)	2%	3% (0-12%)	1%	10% (1-38%)	5%	0.094
Seedlings (%)	16% (0-41%)	2%	12% (0-33%)	2%	28% (10-41%)	4%	0.007
Sage/shrub (%)	14% (0-45%)	3%	18% (0-45%)	3%	3% (0-12%)	2%	0.004
Open/grassland/rocks (%)	4% (0-13%)	1%	4% (0-13%)	1%	1% (0-3%)	0%	0.042

TABLE 21. Comparison of percent cover types measured at spatial Levels 3-5 for goshawk home range areas. P values indicate results of MRPP comparisons. Percent cover types were determined using ARC/INFO vegetation coverages for goshawk territories occupied 1989-1993.

Vegetation Class	LEVEL 5 Foraging Area (2428 ha) mean	SE	(range)	LEVEL 4 PFA (162 ha) mean	SE	(range)	LEVEL 3 Nest Area (81 ha) mean	SE	(range)	Levels 3/5 MRPP p-value	Levels 4/5 MRPP p-value
Mature sawtimber (%)	61%	2%	(34-87%)	66%	4%	(16-100%)	68%	4%	(24-100%)	0.057	0.287
Young sawtimber (%)	5%	2%	(0-38%)	6%	2%	(0-29%)	3%	1%	(0-35%)	0.363	0.318
Seedlings (%)	16%	2%	(0-41%)	17%	4%	(0-64%)	20%	4%	(0-61%)	0.096	0.431
Sage/shrub (%)	14%	3%	(0-45%)	7%	2%	(0-34%)	6%	2%	(0-49%)	0.008	0.051
Open/grassland/rocks (%)	4%	1%	(0-13%)	4%	2%	(0-43%)	3%	1%	(0-20%)	0.014	0.082

TABLE 22 . Comparison of habitat characteristics measured at goshawk nest sites and paired random plots. SD = standard deviation. Center tree refers to the nest tree at nest site plots. Probability levels ai the results of multi-response permutation procedure for matched pairs. Significant differences less than p=0.01 are indicated by **.

Variable	n	Nest Sites mean		Nest Sites SD	Random Sites mean		Random Sites SD	P-value	
Dist to bottom of canopy (m)	26	14.7	±	3.2	10.8	±	4.1	0.000	**
Center tree height (m)	26	24.9	±	5.7	20.5	±	4.9	0.002	**
Main canopy height (m)	26	25.2	±	5.6	21.3	±	5.0	0.004	**
Basal area (sq m/ha)	26	28.5	±	10.7	21.2	±	10.6	0.005	**
Distance to edge (m)	26	327	±	346	172	±	314	0.009	**
Mean DBH snags (cm)	26	15.2	±	6.2	13.6	±	5.2	0.079	
#Downed mature logs/plot	22	49	±	67	28	±	34	0.134	
Percent slope (%)	26	20	±	13	25	±	17	0.144	
Mean DBH sawtimber (cm)	26	31.0	±	6.6	28.9	±	7.4	0.151	
#Saplings/plot	25	23	±	34	19	±	17	0.231	
Site canopy cover (%)	25	75	±	15	71	±	15	0.249	
Center tree canopy cover (%)	23	81	±	12.6	76	±	17.9	0.285	
Density sawtimber (trees/ha)	26	387	±	142	347	±	195	0.292	
Mean ground cover height (cm)	26	21.8	±	12.1	18.7	±	5.9	0.380	
Distance to road (m)	26	1262	±	908	1112	±	992	0.394	
Density of snags (snags/ha)	26	313	±	217	249	±	216	0.404	
#Seedlings/plot	23	104	±	172	143	±	170	0.452	
#Shrubs/plot	25	6	±	16	3	±	5	0.457	
Center tree DBH (cm)	26	41.2	±	16.2	38.2	±	11.2	0.466	
Distance to water (m)	26	543	±	619	612	±	864	0.529	
Canopy depth (m)	26	10.5	±	4.6	10.5	±	4.5	0.554	
Elevation (m)	26	2124	±	122	2140	±	151	0.568	

TABLE 23 . Comparison of size classes of live trees measured at goshawk nest site plots and paired random sites. SE=standard error. Range is given in parentheses. Probability levels are the results of multi-response permutation procedure for matched pairs. Asterisks indicate significant results.

Size Class	Nest Sites mean SE (n=26)	Random Sites mean SE (n=26)	P-value	
#Live trees/plot 7.6-15.1 cm DBH (3.0-5.9")	15.0 ± 3.6 (0-85)	19.2 ± 3.6 (1-80)	0.464	
#Live trees/plot 15.2-22.7 cm DBH (6.0-8.9")	22.2 ± 4.1 (2-104)	21.6 ± 4.4 (0-103)	0.983	
#Live trees/plot 22.8-30.3 cm DBH (9.0-11.9")	15.4 ± 2.4 (0-57)	12.5 ± 2.2 (1-45)	0.203	
#Live trees/plot 30.4-37.9 cm DBH (12.0-14.9")	9.7 ± 1.6 (0-34)	7.3 ± 1.5 (0-29)	0.192	
#Live trees/plot 38.0-45.5 cm DBH (15.0-17.9")	4.9 ± 0.9 (0-18)	2.7 ± 0.5 (0-9)	0.053	**
#Live trees/plot 45.6-53.2 cm DBH (18.0-20.9")	2.3 ± 0.5 (0-9)	1.8 ± 0.3 (0-4)	0.504	
#Live trees/plot 53.3-60.8 cm DBH (21.0-23.9")	1.2 ± 0.3 (0-5)	0.8 ± 0.2 (0-4)	0.642	
#Live trees/plot > 60.9 cm DBH (>24" DBH)	1.0 ± 0.3 (0-7)	0.5 ± 0.3 (0-6)	not run	

TABLE 24. Comparison of size classes of snags measured at goshawk nest site plots and paired random sites. SE= standard error. Range is given in parentheses. Probability levels are the results of multi-response permutation procedure for matched pairs.

Snag Size Class	Nest Sites mean ± SE (n=26)	Random Sites mean ± SE (n=26)	P-value
#Snags/plot 2.5-7.6 cm dbh (1.0-3.0")	9.8 ± 1.8 (0-27)	6.5 ± 1.4 (0-31)	0.107
#Snags/plot 7.6-15.1 cm dbh (3.0-5.9")	18.6 ± 2.7 (0-57)	14.8 ± 2.6 (0-56)	0.278
#Snags/plot 15.2-22.7 cm dbh (6.0-8.9")	8.0 ± 1.4 (0-32)	6.7 ± 1.6 (0-39)	0.846
#Snags/plot 22.8-30.3 cm dbh (9.0-11.9")	3.1 ± 1.0 (0-23)	2.6 ± 1.2 (0-33)	0.579
#Snags/plot 30.4-37.9 cm dbh (12.0-14.9")	0.8 ± 0.2 (0-5)	1.0 ± 0.6 (0-14)	0.548
#Snags/plot 38.0-45.5 cm dbh (15.0-17.9")	(only 5/26 nest plots had snags in this size class)		
#Snags/plot 45.6-53.2 cm dbh (18.0-20.9")	(only 2/26 nest plots had snags in this size class)		
#Snags/plot 53.3-60.8 cm dbh (21.0-23.9")	(only 1/26 nest plot had snags in this size class)		
#Snags/plot > 60.9 cm dbh (>24" DBH)	(no nest plots had snags in this size class)		

TABLE 25. Summary of goshawk territory survey results 1989-1995, Targhee NF. Shown are the number of number of young produced per nest or survey level for each year. Shaded cells indicate data collected prior to timber harvesting at a territory. These pre-harvest data were not used to calculate summary data on territory productivity and occupancy which reflect current conditions at a territory. Occupancy was calculated only for those territories with three or more years of survey data.

		NUMBER OF YOUNG PRODUCED OR SURVEY LEVEL*							Current Conditions				
	TERR#	1989	1990	1991	1992	1993	1994	1995	# Young Produced	# Years Occupied	Average # Young	# Years Surveyed	Occupancy Rate
1	D1-02	2	2	3	2	b	c	c	9	4	2.25	5	0.80
2	D1-03	c	c	c	3	c	c	c	3	1	3.00	1	
3	D1-04	b	2	0	c	1	3	b	4	2	2.00	3	0.67
4	D1-06	c	3	2	4	0	3	0	12	6	2.00	6	1.00
5	D1-08		c	a	2	2	3	a	7	3	2.33	5	0.60
6	D1-09	3	c	c	c	a	c	b	3	1	3.00	3	0.33
7	D1-10	c	c	2	0	a	2	0	4	4	1.00	5	0.80
8	D1-11	3	2	2	2	a	c	c	4	2	2.00	3	0.67
9	D1-12					1	b	2	3	2	1.50	3	0.67
10	D1-13					2	b	0	2	2	1.00	3	0.67
11	D2-01	1	b	c	2	b	b	b	3	2	1.50	6	0.33
12	D2-02	b	c	c	2	2	b	b	2	1	2.00	3	0.33
13	D2-03		3	o	a	c	b	c	3	2	1.50	3	0.67
14	D2-04		3	c	1	o	2	a	6	4	1.50	5	0.80
15	D2-05			1	1	a	b	c	2	2	1.00	4	0.50
16	D2-06				2	a	c	c	2	1	2.00	2	
17	D2-07				2	a	c	c	2	1	2.00	2	
18	D3-01		1	c	0	a	b	b	1	2	0.50	5	0.40
19	D3-06	3	c	c	c	c	b		3	1	3.00	2	
20	D3-07	1	c	c	c	c	b		1	1	1.00	2	
21	D4-01	0	c	0	2	b	a	2	4	3	1.33	5	0.60
22	D4-04	c	c	2	2	2	c	2	8	4	2.00	4	1.00
23	D5-03			2	3	1	c	1	7	4	1.75	4	1.00
24	D5-07	1	2	2	3	a	c	a	3	1	3.00	3	0.33
25	D5-09		2	2	3	1	3	0	9	5	1.80	5	1.00
26	D5-10			1	1	1	2	3	8	5	1.60	5	1.00
27	D5-11				4	3	3	3	13	4	3.25	4	1.00
	mean								4.7	2.6	1.88	3.7	0.69
	sd								3.28	1.50	0.72	1.3	0.25
	min								1	1	0.50	1	0.3
	max								13	6	3.25	6	1.0

* Key to Survey Level: a--one mile searched around nest, b--0.5 mile searched, c--nest stands checked, o--occupied but not active, adults defending nest early in season.

Table 26. Comparison of percent cover types at three spatial levels (nest area, post-fledgling area and foraging area) between high (>50%) and low occupancy (equal or less than 50%) goshawk territories monitored at least three years, 1989-1993, TNF. P values give probability determined using MRPP statistical tests. Asterisks indicate p values below 0.05.

Spatial Analysis Area	Cover Type	High Occupancy Territories (n=16) mean (SD)	Low Occupancy Territories (n=6) mean (SD)	P value
Nest Area	mature forest	78.8 (16.1)	58.2 (12.8)	0.011*
	young forest	0.4 (1.3)	5.3 (4.5)	0.001*
	seedling	10.7 (15.4)	33.8 (16.9)	0.006*
	shrub/sage	insufficient data		
	open	2.9 (6.3)	2.8 (6.9)	0.989
Post-fledging Area	mature forest	71.7 (16.5)	54.8 (19.2)	0.054*
	young forest	2.2 (3.9)	12.5 (10.2)	0.002*
	seedling	11.6 (15.1)	28.3 (19.9)	0.046*
	shrub/sage	9.3 (11.6)	2.0 (2.8)	0.147
	open	5.2 (11.1)	2.2 (3.7)	0.528
Foraging Area	mature forest	62.8 (11.8)	59.3 (10.3)	0.532
	young forest	2.6 (3.3)	6.7 (5.0)	0.036*
	seedling	12.7 (10.4)	23.5 (15.3)	0.070
	shrub/sage	18.1 (13.1)	7.0 (6.0)	0.063
	open	4.1 (4.1)	3.8 (4.6)	0.887

Table 27. Monitoring results at goshawk territories pre and post-timber harvest. Shown are the number of young produced per nest or the survey level per year. Occupancy rate was calculated only for territories monitored for two or more years at survey level A or B.
* indicates small buffer left around known nests < 10 ha. ** indicates large buffer left around known nests > 40 ha.
See Table 17 for key to survey level.

TERR#	YEAR HARVEST	1989	Number of Young Produced or Survey Level 1990	1991	1992	1993	1994	1995	#Years Surveyed	#Years Used	# Young Produced Per Nest	Occupancy Rate
PRE-HARVEST PERIOD												
D1-04	1991	b	2	0					3	2	1.00	0.67
D1-11	1990	3	2						2	2	2.50	1.00
D2-02	1992	b	c	c	2				2	1	2.00	0.50
D4-01	1990	0	c						1	1	0.00	
D5-07	1991	1	2	2					3	3	1.67	1.00
D5-09	1991		2						1	1	2.00	
Mean									2.0	1.7	1.53	0.79
SD									0.9	0.8	0.90	0.25
POST-HARVEST PERIOD												
D1-04	1991				c	1	3	b	3	2	2.00	0.67
D1-09*	1987	3	c	c	c	a	c	b	3	1	3.00	0.33
D1-10**	1989	c	c	2	0	a	2	0	5	4	1.00	0.80
D1-11	1990			2	2	a	c	c	3	2	2.00	0.67
D2-02*	1992					2	b	b	3	1	2.00	0.33
D4-01**	1990			0	2	b	b	2	5	3	1.33	0.60
D5-01	1986			b	a	b			3	0		0.00
D5-05*	1986		b	b	c	c	c		2	0		0.00
D5-07*	1991				3	a	c	a	3	1	3.00	0.33
D5-09**	1991			2	3	1	3	0	5	5	1.80	1.00
Mean									3.50	1.90	2.02	0.47
SD									1.08	1.66	0.71	0.33

Table 28. Comparison of percent mature forest cover at three spatial levels (nest area, post-fledgling area and foraging area) between post-harvest high occupancy (>50%) and low occupancy (50% or less) goshawk territories monitored at least three years, 1989-1995, TNF. P values show results of MRPP statistical comparisons. Asterisks indicate significant values. Occupancy rate at high territories was 72% (SD=33) versus 27% (SD=19) at low territories (MRPP, p=0.002).

		Percent Mature Forest Cover		
Post-harvest Spatial Analysis Area	Cover Type	High Occupancy Territories (n=8) mean (SD)	Low Occupancy Territories (n=7) mean (SD)	MRPP P value
Nest Area	mature forest	73 (14)	50 (9)	0.004*
Post-fledging Area	mature forest	65 (13)	50 (18)	0.162
Foraging Area	mature forest	59 (11)	57 (9)	0 808

TABLE 29. Percent cover types measured at historical nesting territories (n=3) no longer occupied by goshawks. The three territories measured were D3-02, D3-04, D5-01. Shown are the mean, range and standard deviation for cover types at three spatial levels.

		SPATIAL ANALYSIS AREA		
COVER TYPE		NA	PFA	FA
Mature Forest	mean	37%	49%	47%
	range	24-44%	45-58%	40-51%
	SD	1%	7%	6%
Young Forest	mean	1%	1%	1%
	range	0-2%	0-4%	0.6-1.4%
	SD	1%	2%	0%
Seedling	mean	62%	45%	46%
	range	54-76%	35-51%	39-52%
	SD	12%	9%	7%
Sage/shrub	mean	0%	2%	3%
	range	0%	0-4%	2-4%
	SD	0%	2%	1%
Open	mean	0%	2%	3%
	range	0%	1-3%	2-5%
	SD	0%	1%	1%

TABLE 30. Comparison of goshawk nest sites found using a systematic broadcast survey method (n=2) to nest sites found opportunistically on the Targhee NF in Douglas fir habitat (n=37 sites in 15 different territories). Only one distance measure per territory was analyzed. Probability values are shown for the multi-response permutation process (MRPP) test .

Habitat Variable	Survey Nests (n=2)	Other DF Nest Sites		MRPP p value
	mean	mean	(n)	
Nest tree height (m)	31	29	(37)	0.125
Nest height (m)	15	16	(37)	0.760
Nest tree age (years)	131	169	(37)	0.252
Nest tree dbh (cm)	61	58	(37)	0.143
Nes tree canopy cover (%)	85	81	(37)	0.783
Elevation (m)	2197	2146	(37)	0.552
Sawtrees per hecatare	350	464	(30)	0.826
Sawtrees mean dbh (cm)	37	36	(30)	0.291
Snags per hectare	323	281	(30)	0.949
Snag mean dbh (cm)	15	20	(30)	0.730
Ground cover height (cm)	16.6	18.0	(30)	0.934
Slope (%)	33	21	(30)	0.647
Distance to road (m)	1677	1311	(15)	0.299
Distance to water (m)	158	558	(15)	0.316
Distance to edge (m)	934	272	(15)	0.028*

TABLE 31. Comparison of habitat variables at goshawk nesting territories found in management areas classified as unsuitable (n=5) and suitable for timber harvesting (n=22). Habitat variables were measured at nest trees, nest plots and at different spatial levels surrounding nest clusters. MRPP was used to compare groups.

Habitat Variable	Territories in Unsuitable Habitat		Territories in Suitable Habitat		MRPP p value
	mean	(n)	mean	(n)	
Nest tree height (m)	26	8	26	31	0.548
Nest tree dbh (cm)	35.2	8	51.5	31	0.014*
Nest tree age (years)	61	6	147	29	0.348
Nest height (m)	14	8	13	31	0.728
Nest tree canopy cover (%)	91	8	85	27	0.059
Elevation (m)	2138	8	2156	31	0.996
Slope (%)	27	8	24	31	0.176
Distance to edge (m)	124	5	339	22	0.238
Sawtree mean dbh (cm)	31.7	5	30.9	22	0.135
Sawtree density (trees/ha)	392	5	364	22	0.665
Snag mean dbh (cm)	12.7	5	16.2	22	0.294
Snag density (snags/ha)	464	5	278	22	0.205
Basal area (sq meter/ha)	30.4	5	27.2	22	0.192
Site canopy cover (%)	87	5	69	22	0.019*
Number of downfall/ha	22	5	47	22	0.304
NA mature forest cover (%)	66	5	67	22	0.219
PFA mature forest cover (%)	59	5	66	22	0.183
FA mature forest cover (%)	56	5	62	22	0.193

TABLE 32. Comparison of nesting chronology at goshawk study areas in the western United States.

Study Area (Reference)	Start of Incubation		Hatching Date		Fledge Date	
	mean	range	mean	range	mean	range
Eastern Idaho, western WY (this study)	May 5	Ap 20-May 20	June 6	May 22-June21	July 15	July 1-July 30
NE Oregon (Henny et al. 1985)	April 24	Ap 12-May 6	May 24			
Oregon (Reynolds and Wight 1978)	May 6	Ap 10-June 2	early June		mid-July	
NE Oregon (Bull and Hohmann, 1994)		(late Ap-early May)			July 8	June 22-July 27
N. Arizona (Reynolds et al. 1994)		(late Ap-early May)		May 31-June16		July 7-July 25
Nevada (Younk and Bechard, 1994)	May 1				July 6	
Fairbanks, Alaska McGowan, 1975)			June 4	May 25-June 25	July 10	June 22-July 28

TABLE 33. Comparison of goshawk nest site data from western Montana and northern Idaho (Hayward and Escano 1989) with nest sites (one randomly selected per territory) on the Targhee NF. Shown are means, 95% confidence limits and ranges. T values calculated using Student T test. Critical value of T=2.02. *** indicates p<0.001.

	Montana and nothern Idaho (n=17)			Targhee NF (n=27)			T	
Variable	mean	95% CL	range	mean	95% CL	range	value	p
Nest tree height (m)	26	4.41	12-48	26	2.7	12-38		
Nest height (m)	12.5	1.46	7-17	14	1.15	8-21	-1.681	
Nest tree dbh (cm)	50	10.57	25-97	43	6.80	21-84	1.122	
Canopy cover (%)	80	2.71	65-90	77	7.25	29-96	0.695	
Basal area (sq m/ha)	40.6	3.75	29.3-53.8	27.8	4.42	8.7-51.2	4.196	***
Tree density (trees/ha):								
7.6-17.8 cm dbh	615	231	150-1600	177	73.3	8-874	4.764	***
17.8-30.4 cm dbh	393	99	25-725	225	56	16-614	4.002	***
30.4-60.9 cm dbh	143	44	25-275	135	36	0-339	0.282	
>60.4 cm dbh	15	10	0-50	10	6	0-55	0.959	

Table 34. Proportion of mature forest cover at 11 goshawk territories found outside of timber harvest areas on the TNF.

Territory	Mature Forest Cover (%)		
	NA	PFA	FA
D1-02	67%	73%	55%
D1-03	51%	54%	54%
D1-12	100%	99%	81%
D1-13	100%	86%	72%
D2-01	80%	72%	74%
D2-03	100%	99%	84%
D2-04	78%	55%	56%
D3-07	100%	100%	87%
D4-04	99%	89%	65%
D5-10	71%	55%	49%
D5-11	64%	66%	67%
mean	83%	77%	68%
SD	18%	18%	13%

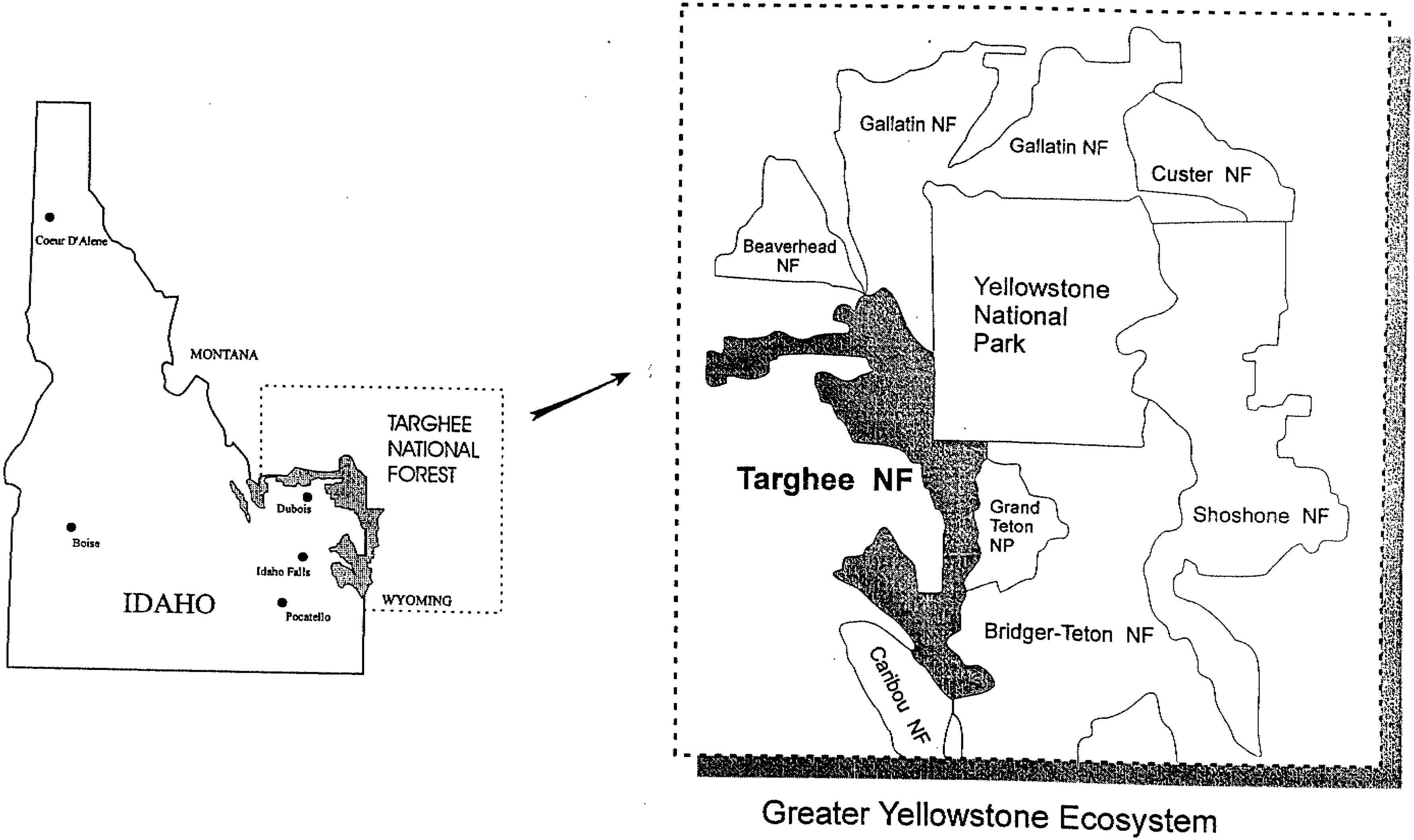


Fig 1. Location of the Targhee National Forest in relation to the state of Idaho and the Greater Yellowstone Ecosystem

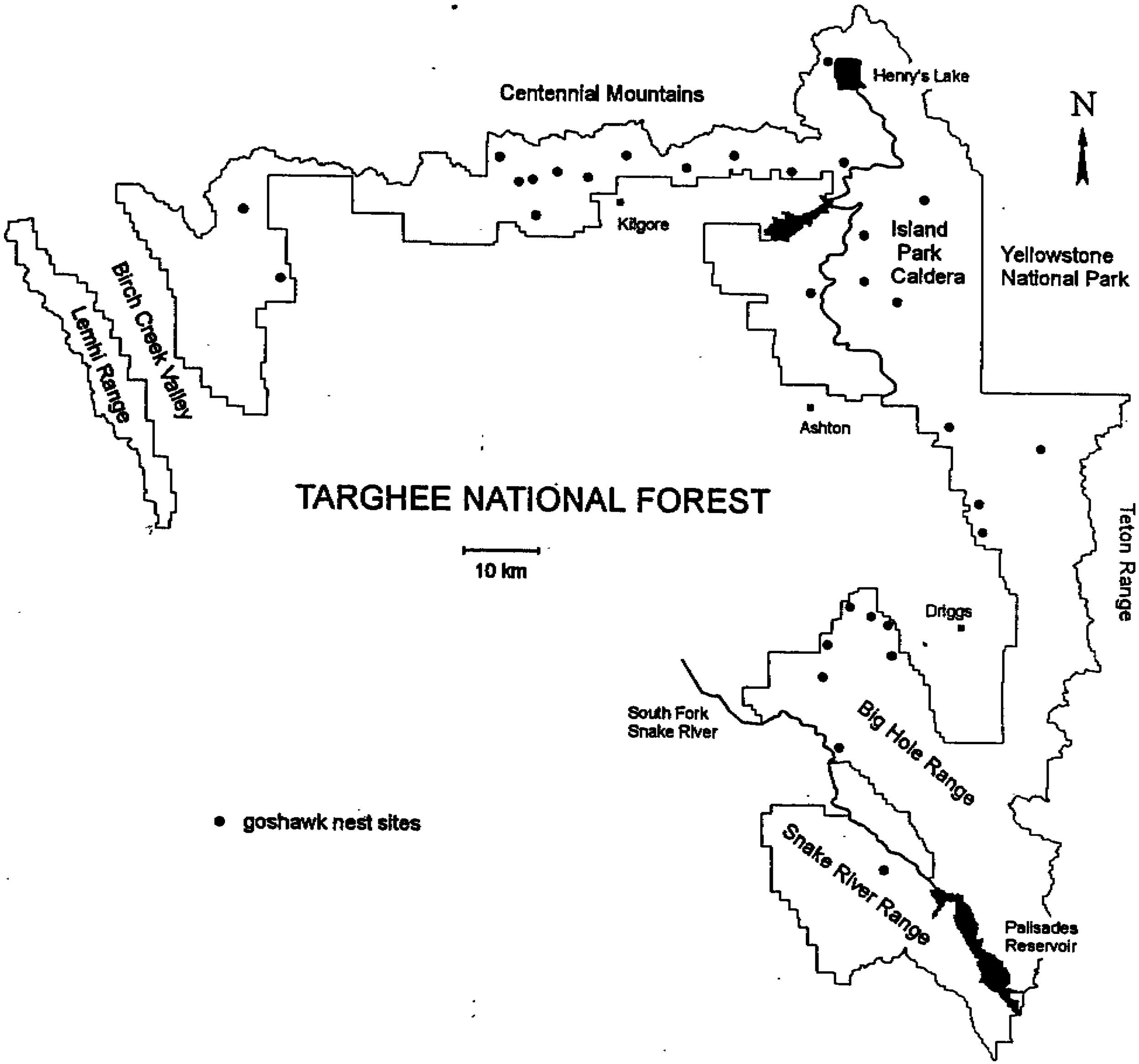


Fig 2. Map of the Targhee National Forest showing major geographical features and approximate locations of goshawk study sites.

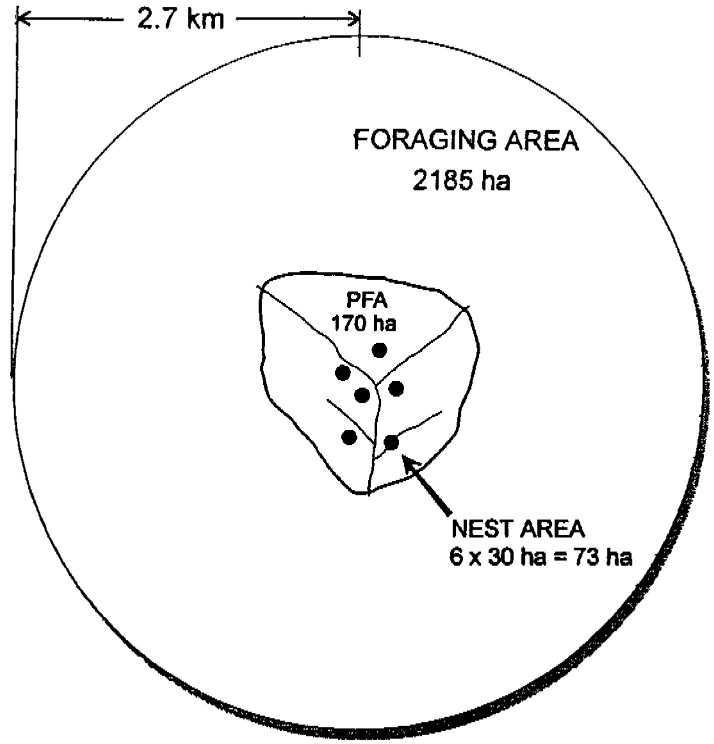


Fig 3a. Schematic diagram of the spatial components of goshawk home range areas as defined in the USDA Forest Service mangement recommendations for the Southwest (Reynolds et al. 1992).

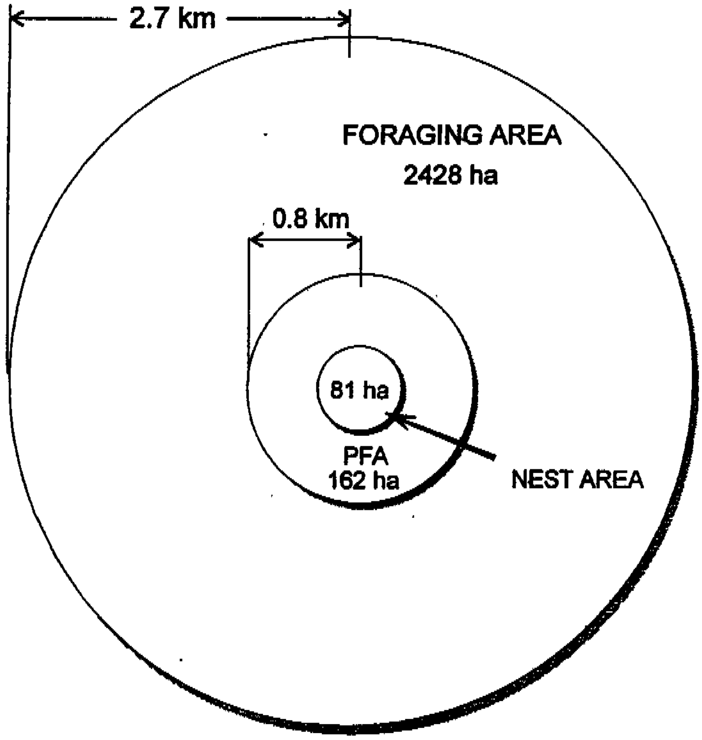


Fig 3b. Schematic diagram of the spatial components of goshawk home range areas used to analyze goshawk nesting habitat on the Targhee National Forest. The foraging area includes the nest area and PFA.

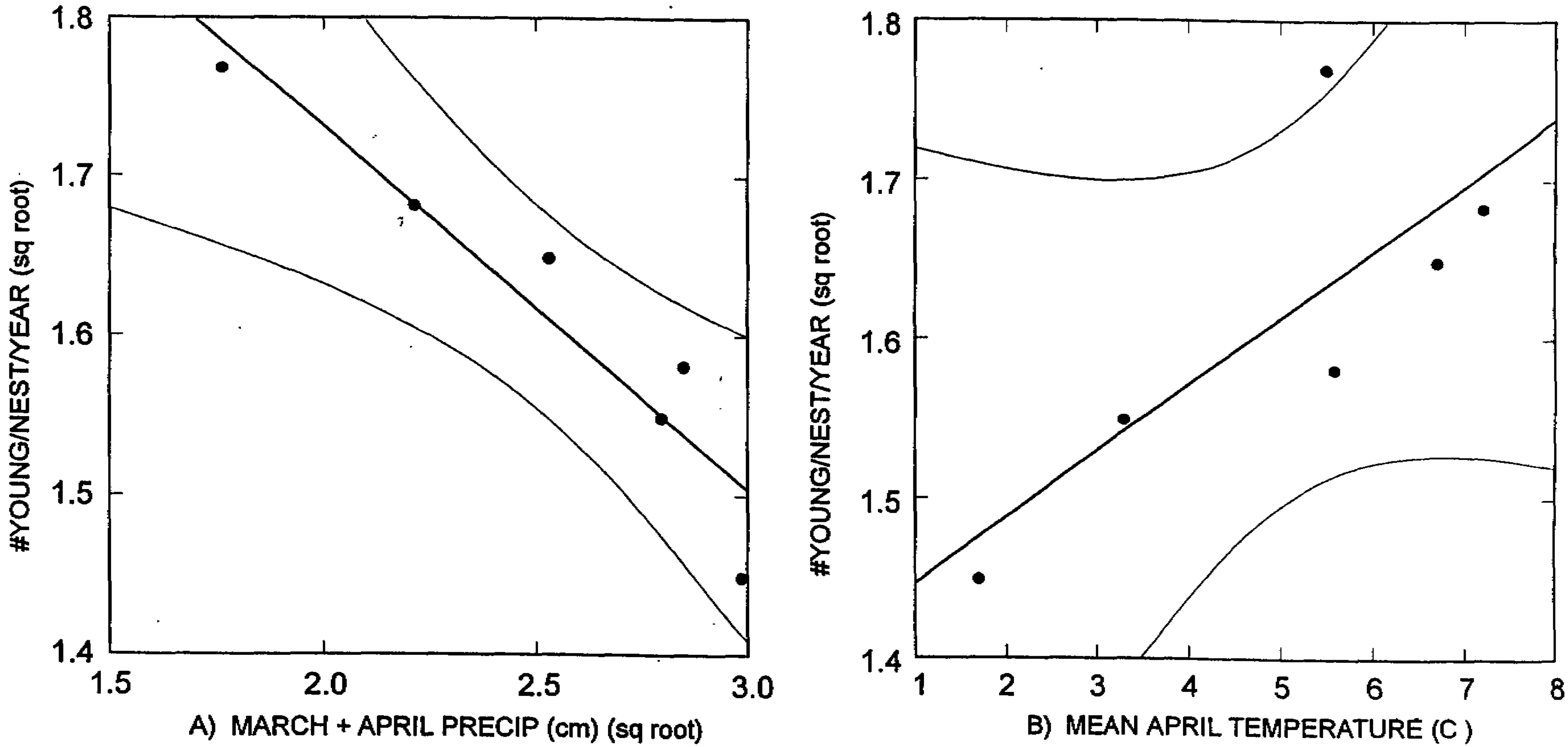


Fig. 4. Linear regressions showing the relation between mean annual goshawk productivity (n=6, 1989-1994) and A) total rainfall in March and April, and B) mean temperature in April. See text for regression equations. Curved lines indicate 95% confidence limits. Productivity and precipitation has been square root transformed.

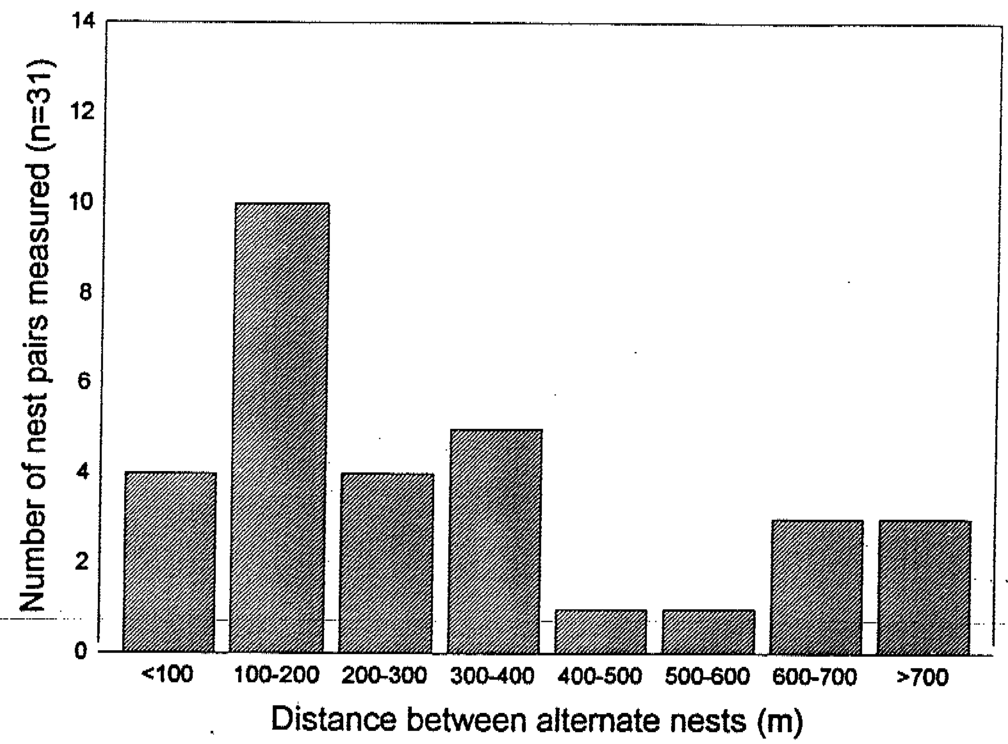


Fig 5. Distribution of inter-nest distances between alternate goshawks nests used within the same territory either one or two years apart.

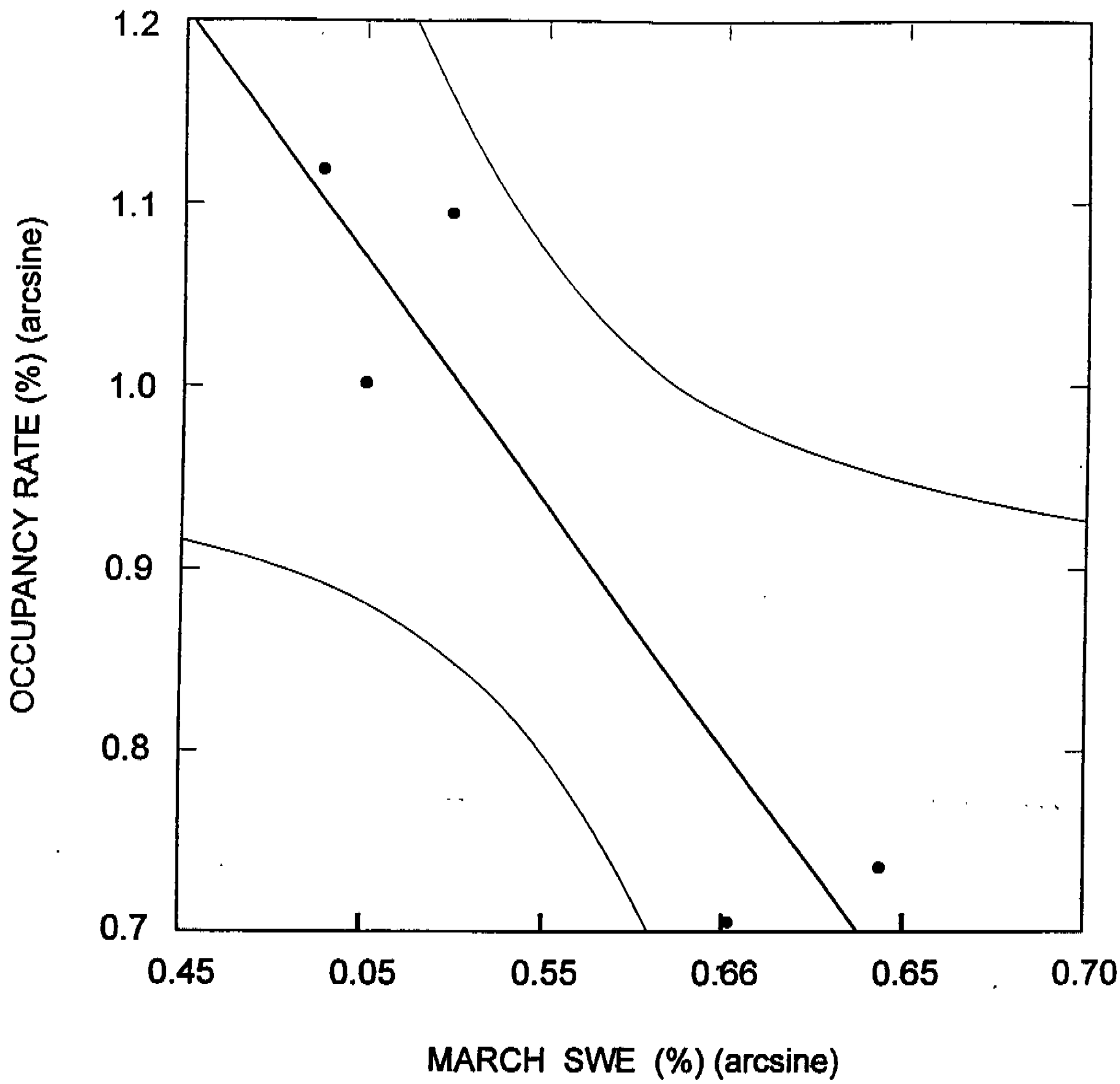


Fig. 6. Linear regression showing the relation between mean annual occupancy rate (%) (n=6, 1989-1994) and snow water equivalent (%) of the snowpack in March. See text for regression equation. Curved lines indicate 95% confidence limits. Variables have been arcsine transformed.

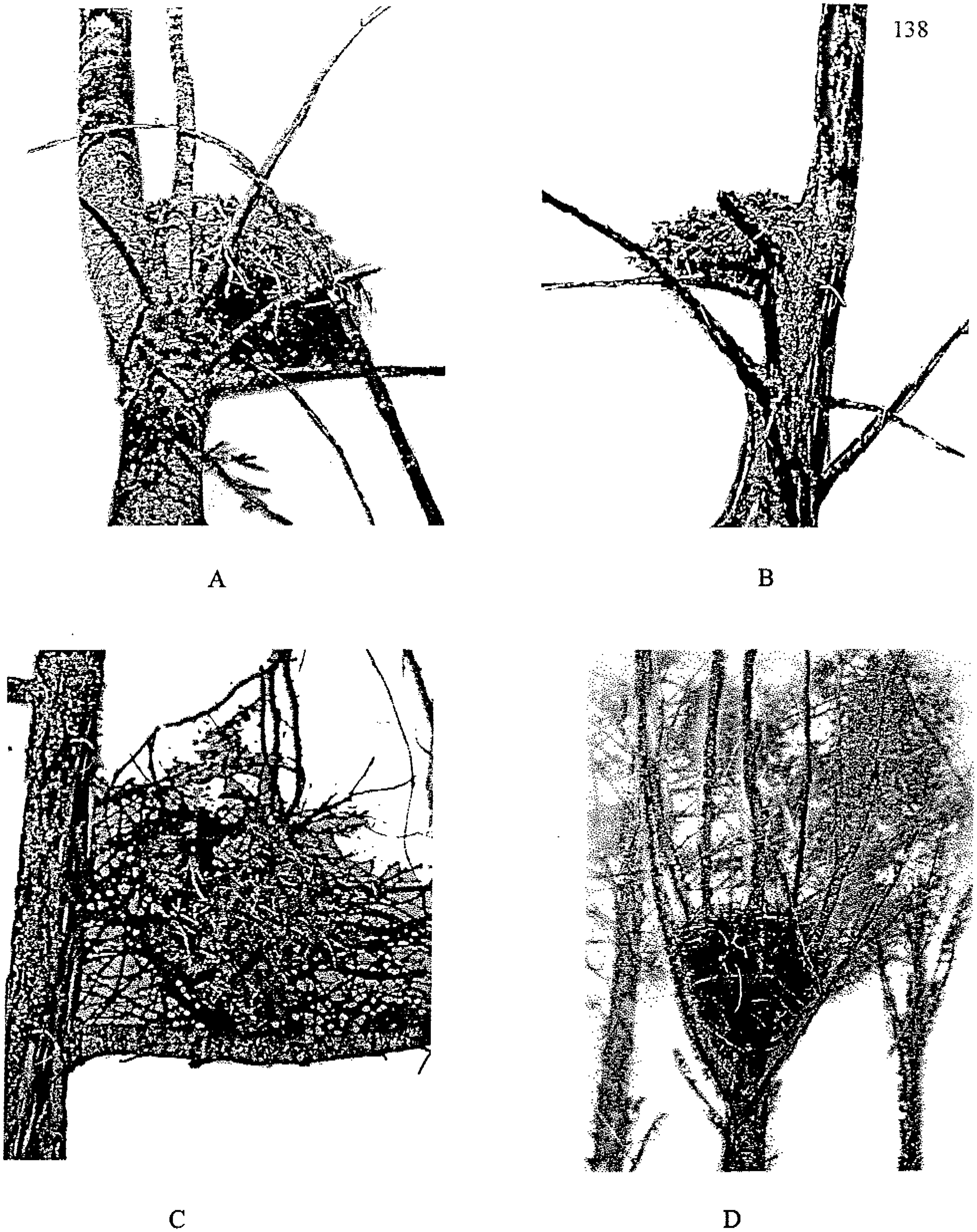


Fig 7. Four types of goshawk nest structures including A) basket nest B) platform nest C) broom nest, and D) broken crown conifer nest.

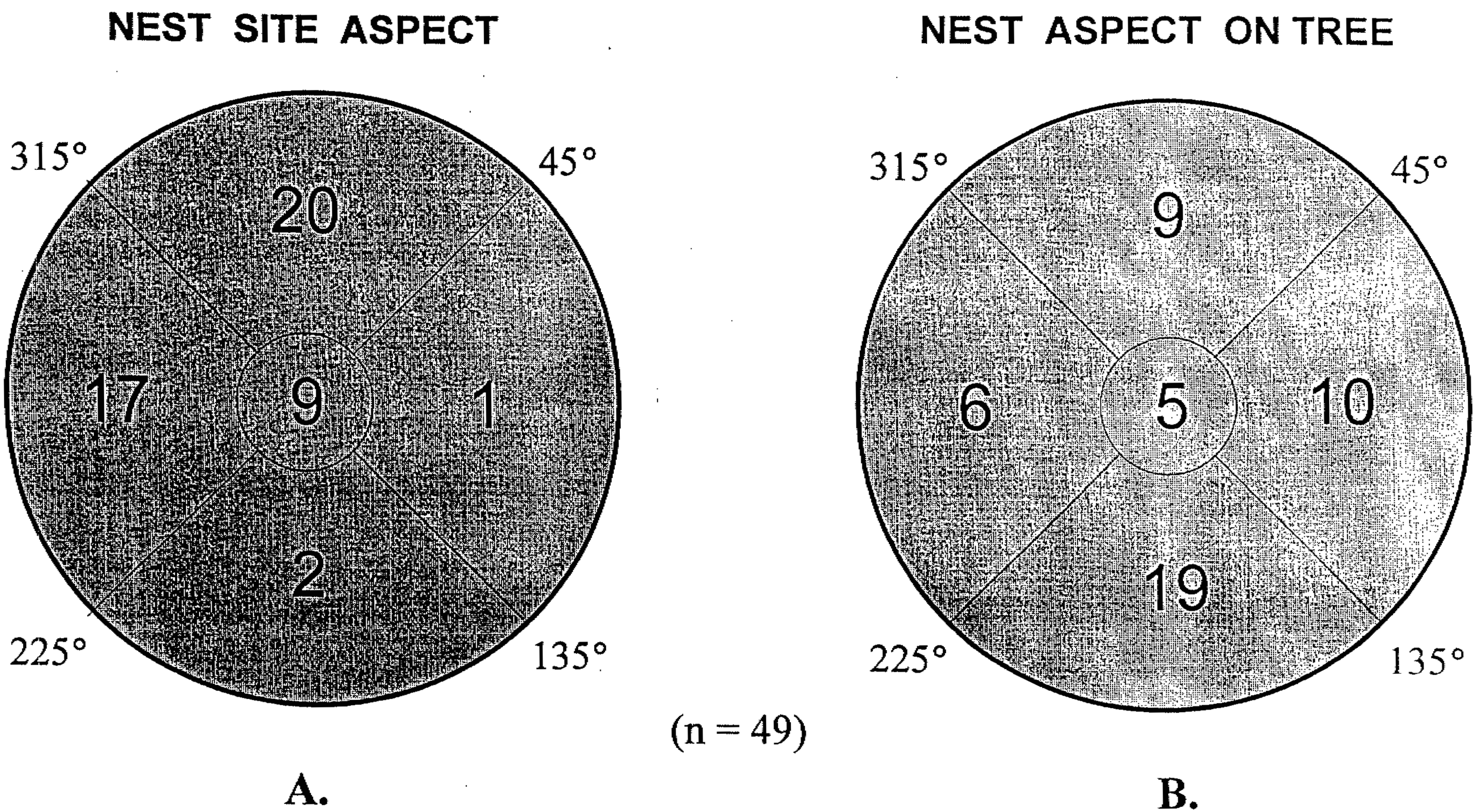
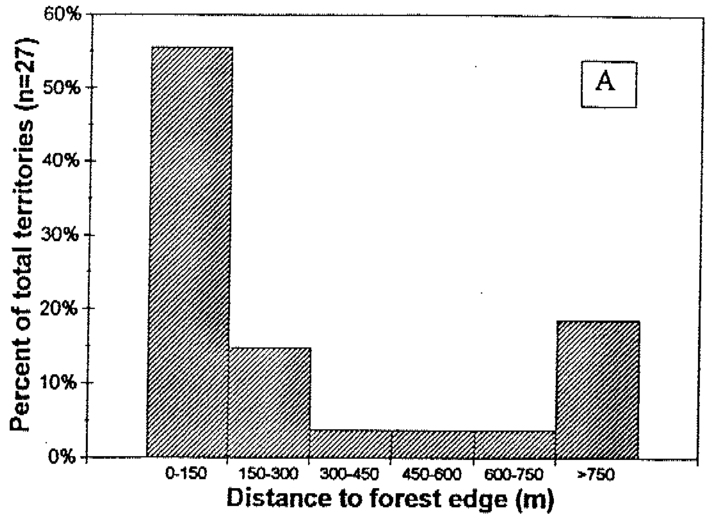


Fig 8. The distribution of aspects of A) goshawk nest sites in relation to topography and, B) goshawk nests in relation to the tree trunk. Numbers in the center of each circle denote sites found on slopes < 5 degrees or nests located on broken crown trees.



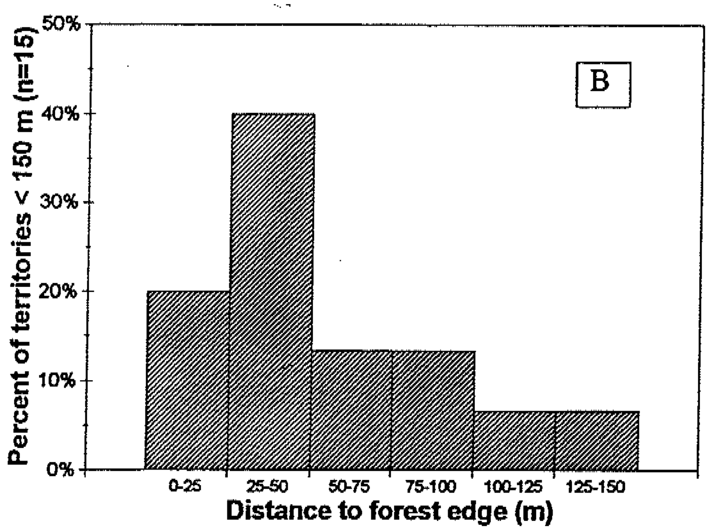


Fig 9. Frequency distribution showing distances from nest clusters to edge of forest. A. Historgram of all current territories (mean=299 m, SE=75). B. Histogram of territories located 150 m or less from forest edge (mean=55 m, SE=10).

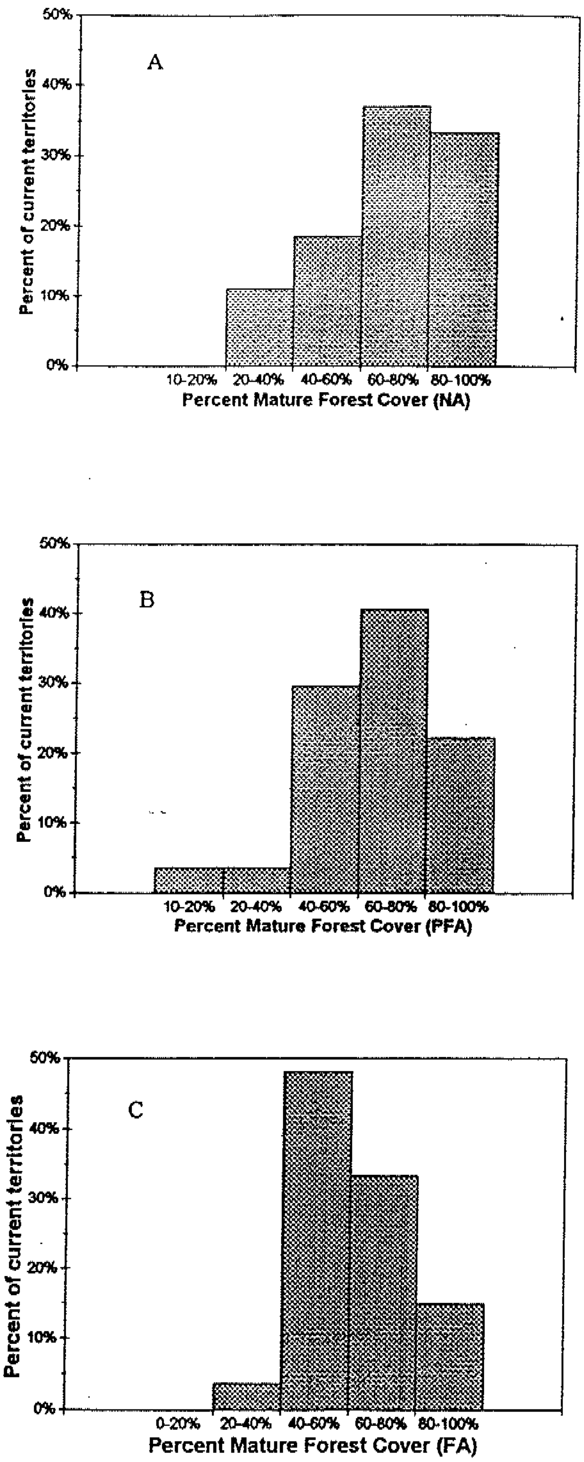


Fig 10. Frequency distribution of mature forest cover at different spacial scales within estimated home range areas at goshawk nesting territories (n=27). A. Nest area (81 ha) B. Post-fledgling family area (162 ha) C. Foraging area (2428 ha)

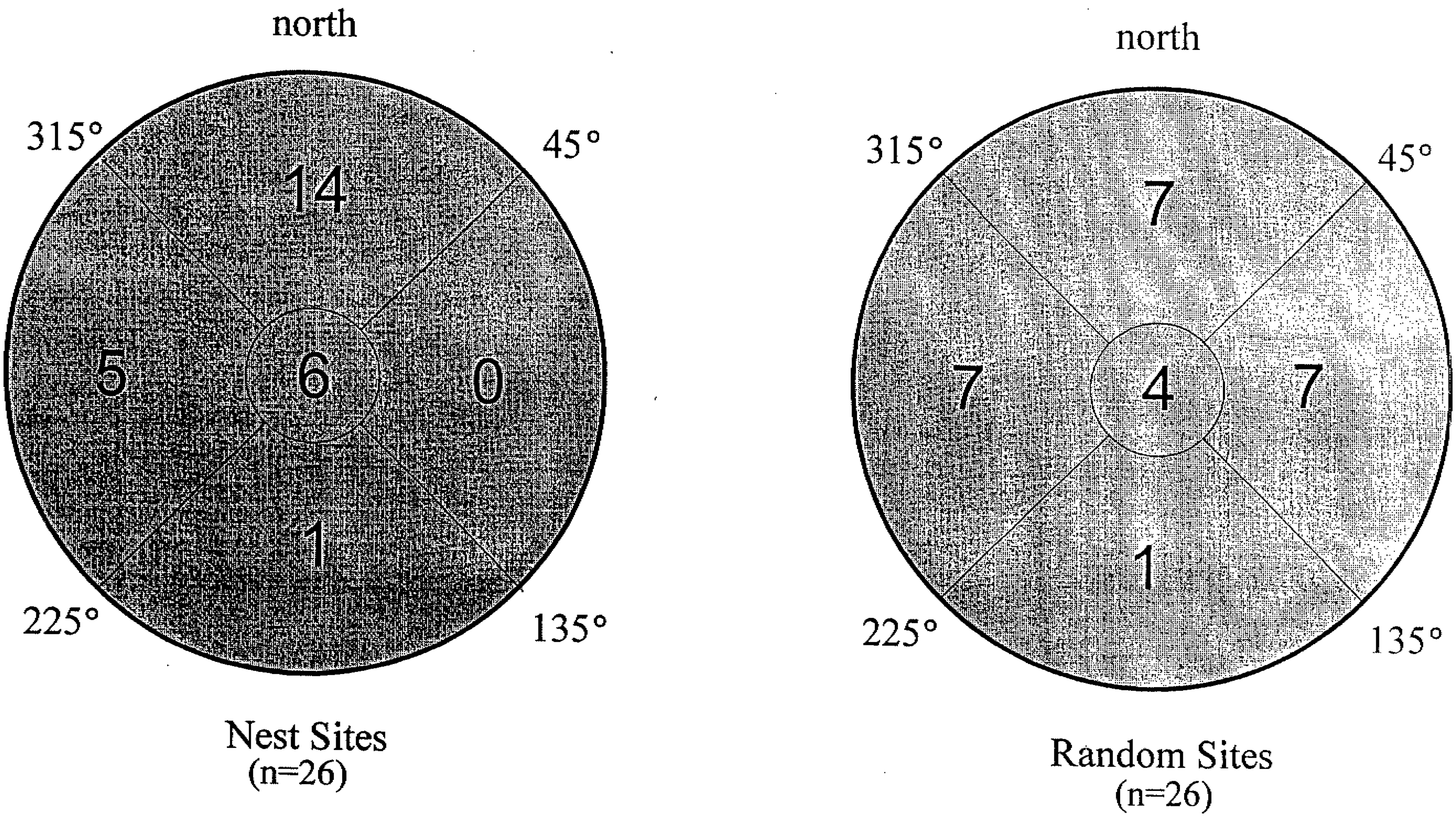


Fig 11. Comparison of slope aspect at nest sites and paired random sites. Numbers in the center of each circle denote sites found on slopes < 5 degrees. Distribution of nest sites was significantly different compared to a uniform distribution (Rao's spacing test).

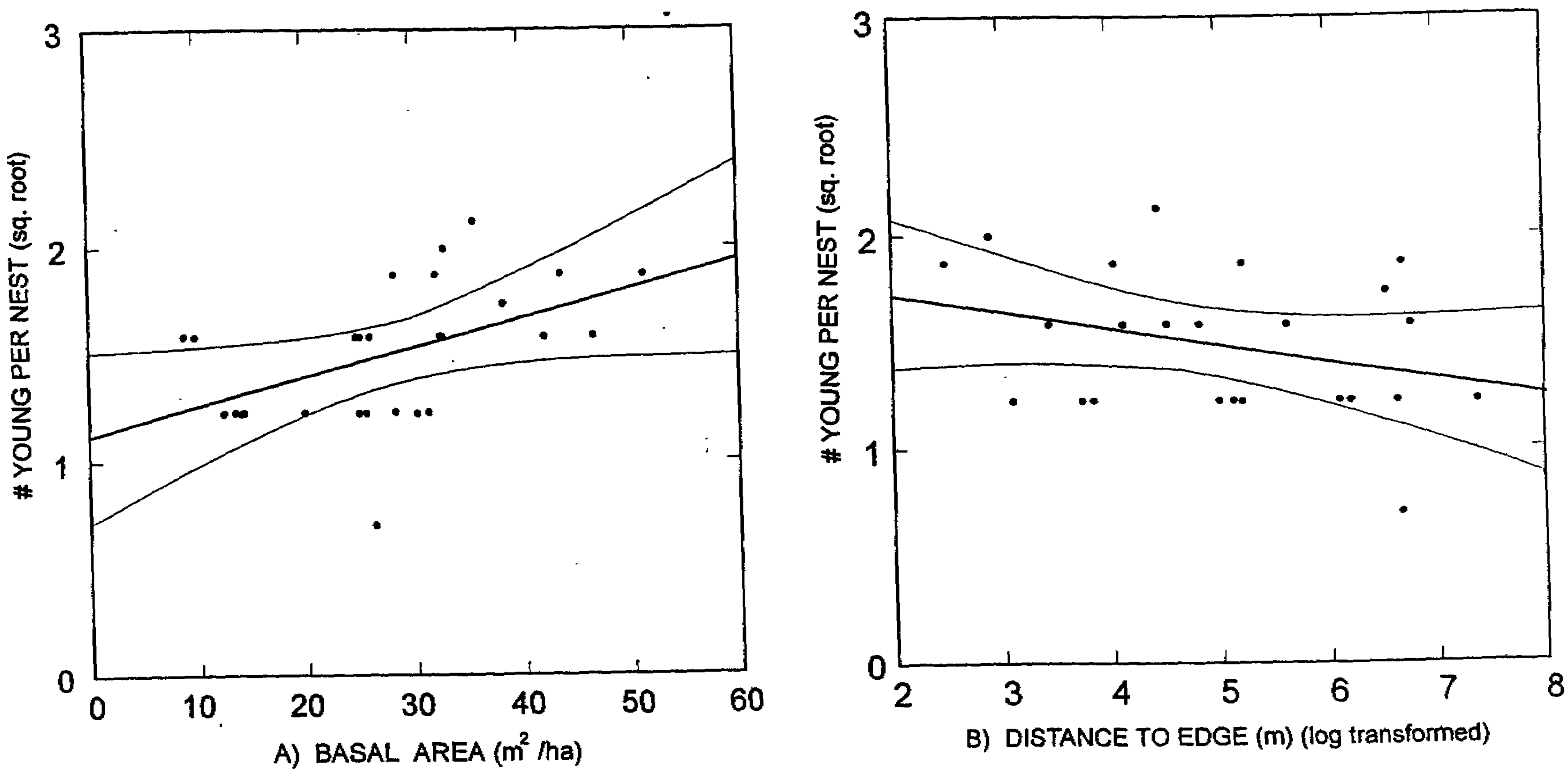


Fig. 12. Linear regression showing the relation between nest site productivity (n=27) and A) basal area of the nest plot, and B) distance of nest site to forest edge (log transformed). See text for regression equation. One nest site per territory was randomly selected for this analysis. Curved lines indicate 95% confidence limits. Productivity data were square root transformed.

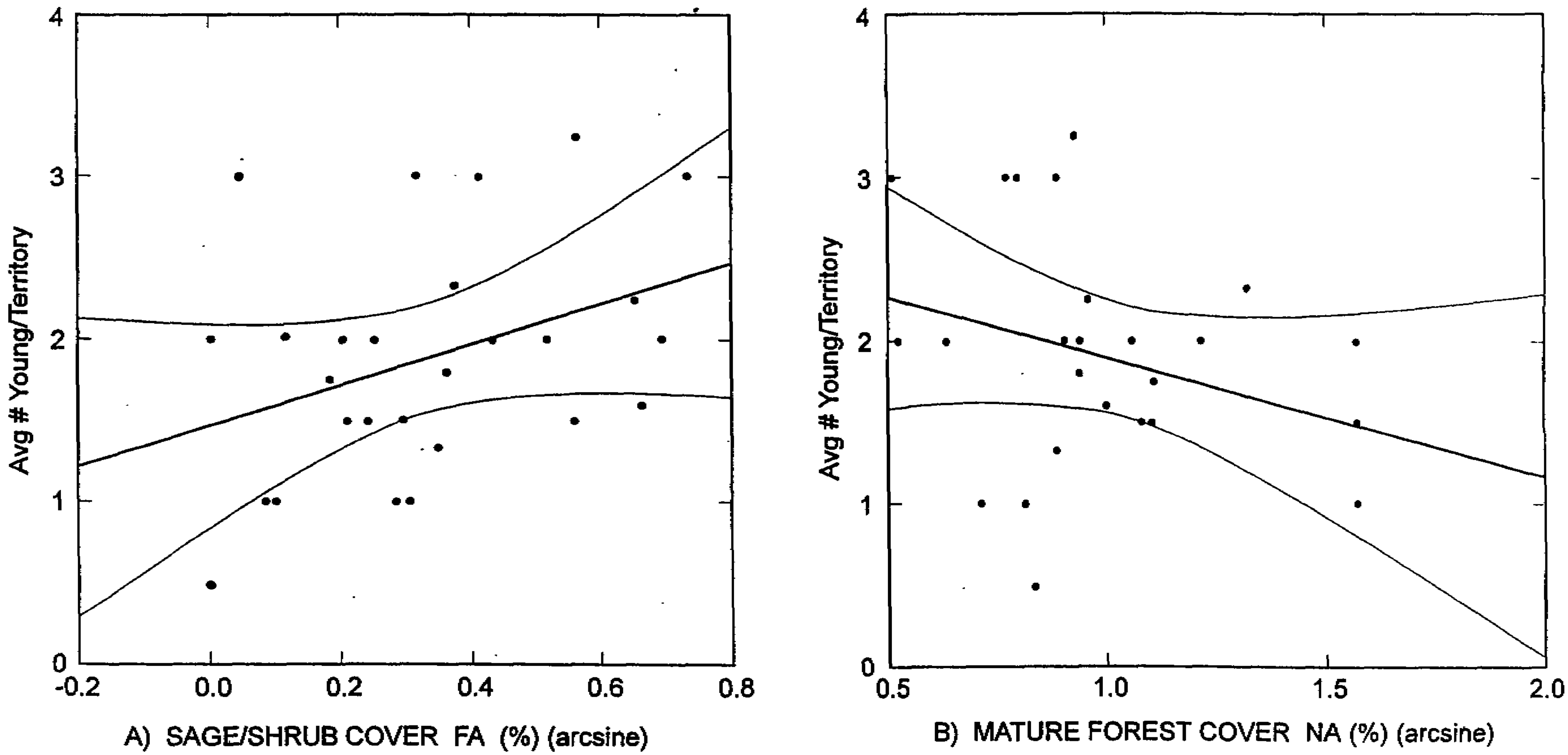


Fig. 13. Linear regressions showing the relation between the average number of young produced per territory (n=27) and A) percent of sage/shrub cover in the foraging area, and B) percent of mature forest cover in the nest area . Curved lines indicate 95% confidence limits. Percent cover types were arcsine transformed. See text for stepwise regression equation.

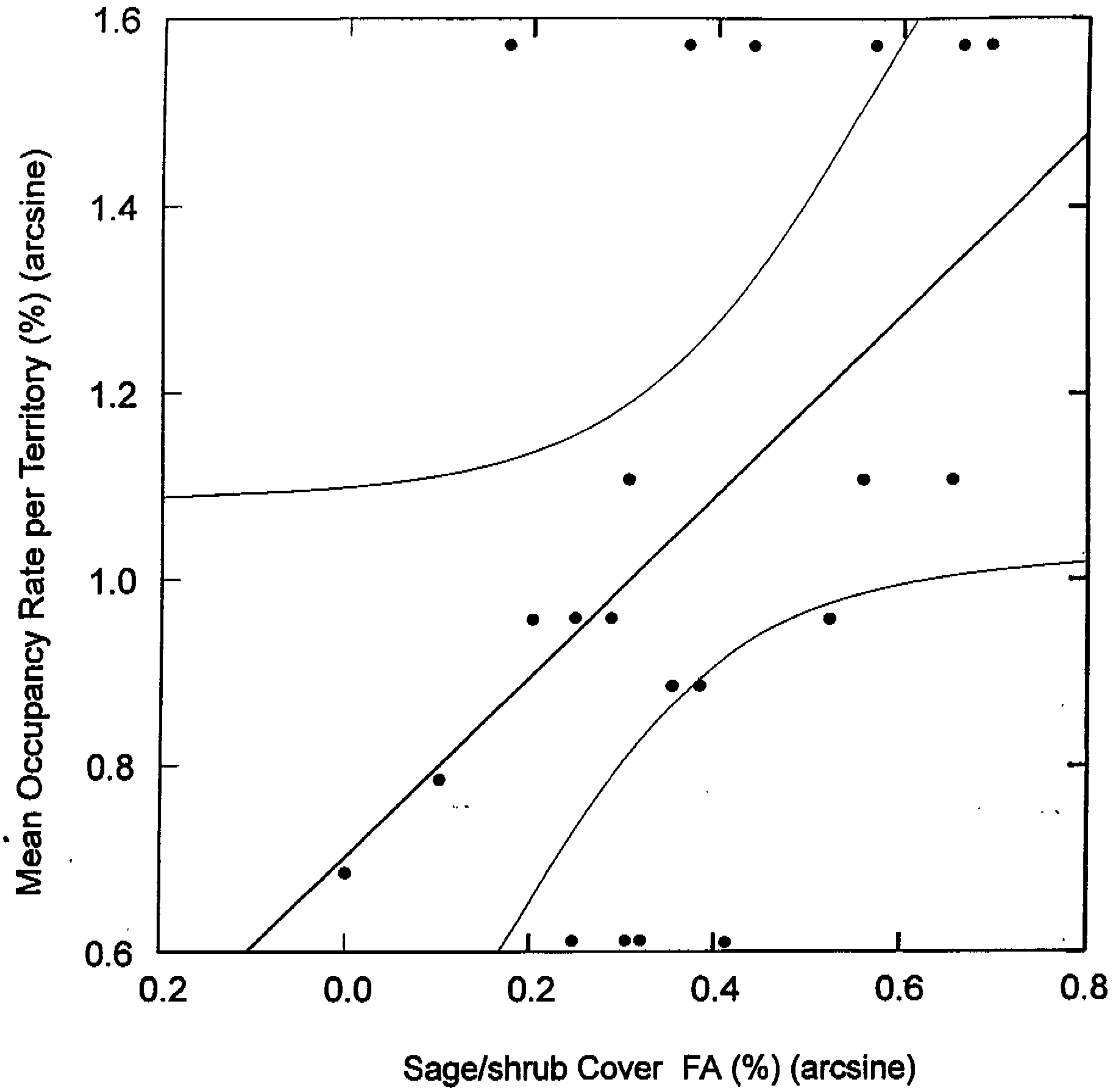


Fig. 14. Linear regression showing the relation between mean territory ocupancy rate (n=27, arcsine transformed) and percent of sage/shrub cover (arcsine transformed) in the foraging area. Curved lines indicate 95% confidence limits. See text for regression equation.

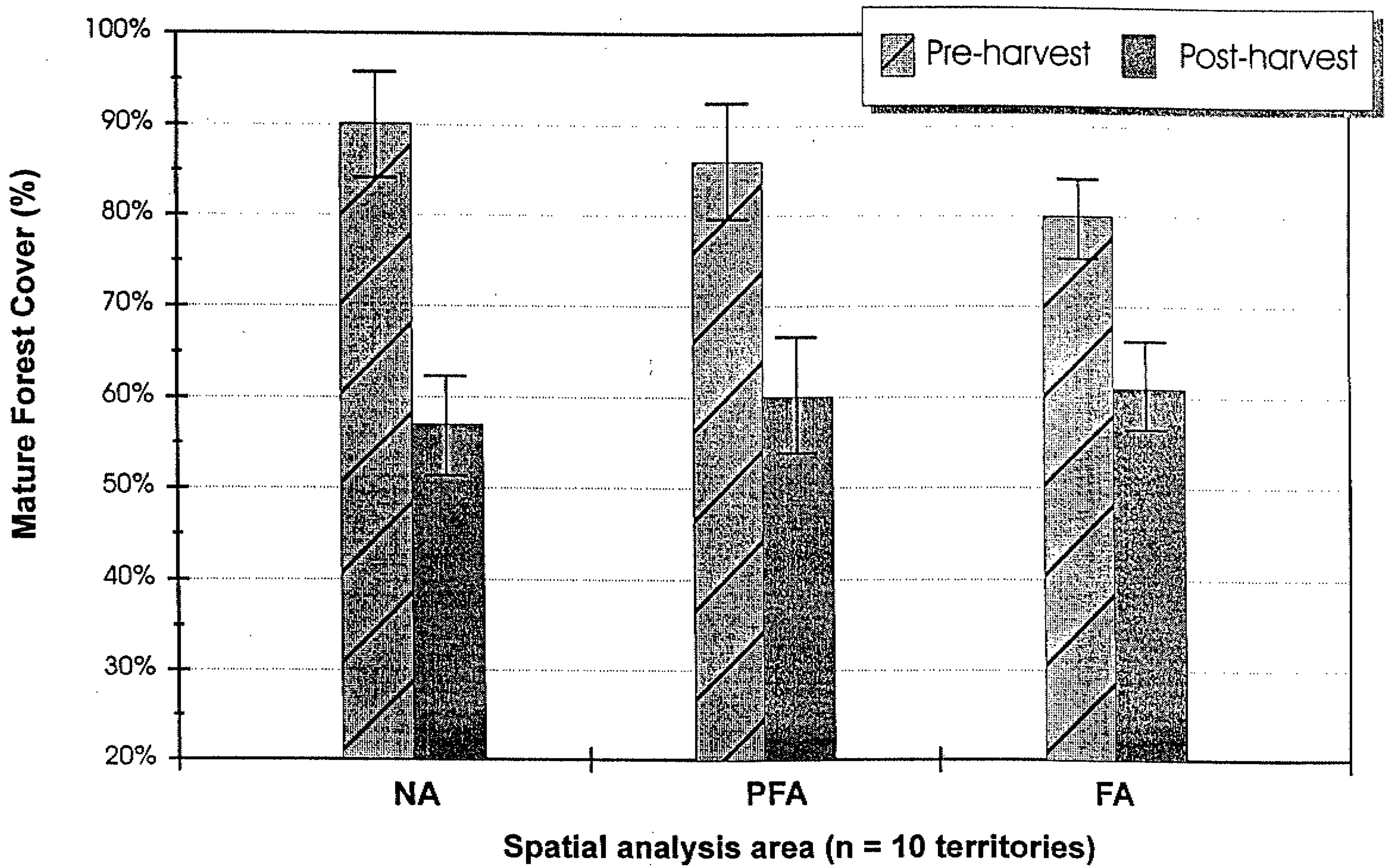


Fig. 15. Comparison of percent mature forest cover pre- and post-harvest at different spatial areas within an estimated home range area surrounding 10 territories on the Targhee NF.

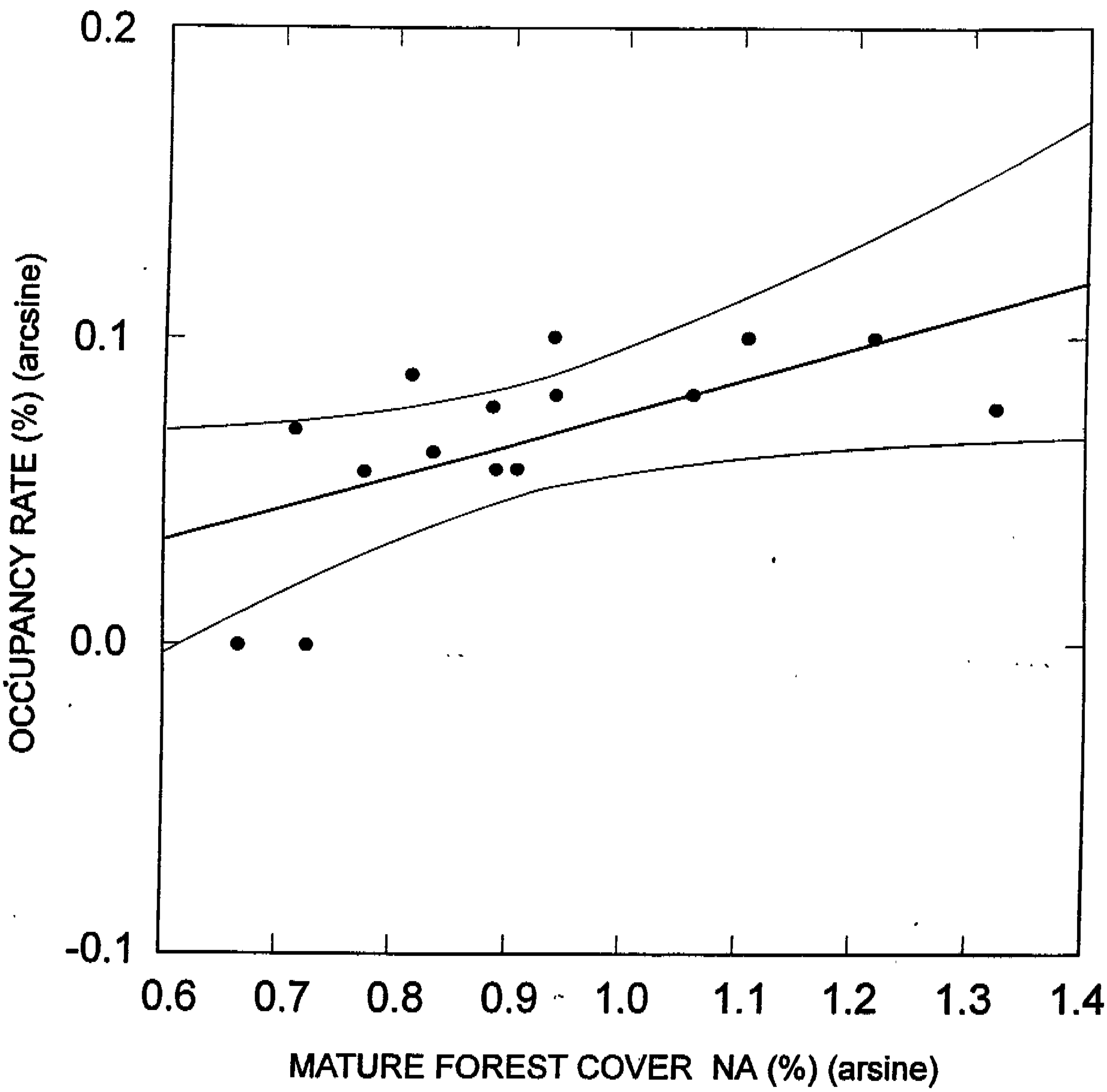


Fig. 16. Linear regression showing the relation of occupancy rate of post-harvest territories (n=15) and the percent of mature forest cover in the nest area. See text for regression equation. Curved lines indicate 95% confidence limits. Percent data have been arcsined transformed.

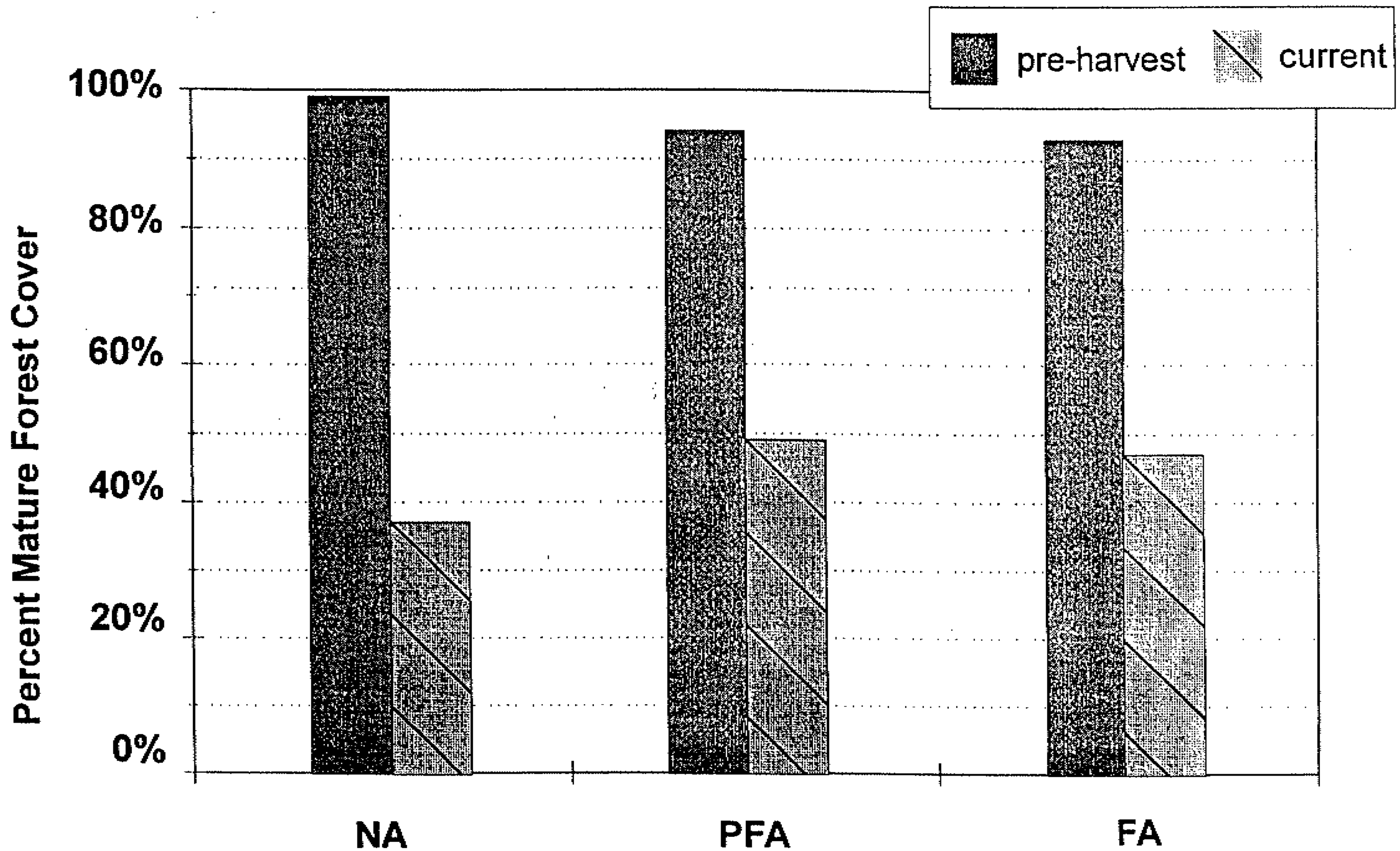


Fig. 17. Comparison of proportion of mature forest cover between pre-harvest and current conditions at three historical territories found in salvage logging timber sale areas where goshawk nests were not found in the current period. Percent forest cover is shown for different spatial components of the home range area. NA = nest area, PFA = post-fledgling family area, and FA = foraging area.

Appendix A-1. List of habitat variables measured at gosahwk nest sites, Targhee NF.

Variable Name	Description
LEVEL 1 variables:	
TREEHT	height of nest tree or center tree
TREEDBH	diameter at breast height of nest or center tree
TREEAGE	age of nest tree
TREESPP	species of nest tree: DF Douglas fir, LP lodgepole pine,, SP Englemann spruce, AS aspen
TREERATE	rating of nest tree in canopy: 1) dominant 2) co-dominant 3) intermediate 4) suppressed
TREECOND	structural condition of nest tree: 0) good 1) deformed
TREECC	canopy cover (percent) measured at nest tree
SLOPEPOS	position of nest tree on slope: 1) bottom third 2) middle third 3) upper third
NESTHT	height of nest
NESTTRHT	proportion of nest to nest tree height
NESTTYPE	type of nest structure: PLAT platform, BASK basket, WHORL mistlewhorl, BRCR broken crown
NUMSUPBR	number of nest support branches
NESTMIST	occurance of mistletoe in nest tree: 0) absent 1) present
SUBRSIZE	size of support branches: 1) small 2) medium 3) large
SUBRCOND	condition of support branches: 1) live 2) dead
NESTCAN	distance of nest below main canopy
NESTASP	orientation of nest in nest tree
SLOPEASP	orientation of slope
SLOPEPER	slope percent
TOPOSITE	description of nest site topogrpahy: 1) flat 2) small drainage 3) slope of ridge 4) top of ridge
DISTNEST	distance to alternate nest
DISTEDGE	distance from nest tree to edge of forest stand or ecotone
EDGETYPE	type of habitat at edge: NM natural meadow, CC clearcut, SC select cut, AG agricultural field
DISTROAD	distance from nest tree to nearest numbered FS road
DISTWATE	distance to the nearest permanant water source
WATETYPE	type of water source: ST stream, PD pond, RS reservoir, SP spring

Appendix A-2. List of habitat variables measured at gosahwk nest stands, Targhee NF.

Variable Name	Description
LEVEL 2 variables:	
CANLAYER	number of canopy layers estimated at nest site
CANHT	height of canopy at nest site of mature trees
CANBTT	height of bottom layer of canopy of mature trees
CANDF	canopy depth of mature trees: CANHT-CANBTT
SITECC	canopy cover (percent) measured on perimeter of plot
GRCOVHT	height of ground cover
SEED	number of seedlings counted per transect (trees < 2.5 cm dbh)
SAP	sumber of saplings counted per plot (trees 2.5-7.6 cm dbh)
SHNUM	number of shrubs counted per transect
SAWTRHA	number of sawtimber per ha counted in plots(trees > 17.8 cm dbh)
SAWDBH	mean diameter of sawtimber within plots
SNAGHA	number of snags counted per ha in plots (dbh > 3.8 cm)
SNAGDBH	mean diameter of snags within plots (dbh > 3.8 cm)
DOWNF	number of downfall trees per plot (dbh > 17.8 cm)
DOWNFSM	amount of smaller woody debris: 1) light 2) moderate 3) heavy
3TO6L	number of live trees in plot 3-6" dbh (7.6-15.1 cm)
6TO9L	number of live trees in plot 6-9" dbh (15.2-22.7 cm)
9TO12L	number of live trees in plot 9-12" dbh (22.8-30.3 cm)
12 TO15L	number of live trees in plot 12-15" dbh (30.4-37.9 cm)
15TO18L	number of live trees in plot 15-18" dbh (38.0-45.5 cm)
18TO21L	number of live trees in plot 18-21" dbh (45.6-53.2 cm)
21TO24L	number of live trees in plot 21-24" dbh (53.3-60.8 cm)
24+L	number of live trees in plot > 24" dbh (> 60.9 cm)
1TO3S	number of snags in plot 1-3" dbh (2.5-7.5 cm)
3TO6S	number of snags in plot 3-6" dbh (7.6-15.1 cm)
6TO9S	number of snags in plot 6-9" dbh (15.2-22.7 cm)
9TO12S	number of snags in plot 9-12" dbh (22.8-30.3 cm)
12 TO15S	number of snags in plot 12-15" dbh (30.4-37.9 cm)
15TO18S	number of snags in plot 15-18" dbh (38.0-45.5 cm)
18TO21S	number of snags in plot 18-21" dbh (45.6-53.2 cm)
21TO24S	number of snags in plot 21-24" dbh (53.3-60.8 cm)
24+S	number of snags in plot > 24" dbh (> 60.9 cm)
TYPESITE	predominant tree species in plot : single species >85% or all species which total 85% or more of plot
BASALAR	basal area of sawtimber in plot

Appendix B. Categories and symbols used for the Targhee NF GIS vegetation classification for the Forest Plan revision (USDA FS 1996).

SYMBOL	VEGETATION CLASS
LP	lodgepole pine
LP9	mature trees, no previous treatment
LP8	pole (3-7" dbh)
LP7	sapling (1"-2.9" dbh)
LP6	seedling (6" height, to 0.99" dbh)
LP5	nonstocked (seedling<6" in height)
DF	Douglas fir
DF9	mature trees, no previous treatment
DF8	pole (3-8" dbh)
DF7	sapling (1"-2.9" dbh)
DF6	seedling (6" height, to 0.99" dbh)
DF5	nonstocked (seedling<6" in height)
MX	Mixed Conifer (DF AND LP, no species more > 85% of total
MX9	mature trees, no previous treatment
MX8	pole (3-7" dbh)
MX7	sapling (1"-2.9" dbh)
MX6	seedling (6" height, to 0.99" dbh)
MX5	nonstocked (seedling<6" in height)
MX3	Mixed Conifer (DF or LP with fir or spruce component)
AS	Aspen
WB	Whitebark pine
SF	Spruce-fir (Englemann spruce and sub-alpine fir)
N	prefix for non-commercial forest
MB	Mountain Brush
W	Willow
GR	Grass
GR/FB	Grass/forb
GR/SA	Grass/sage
GR/BR	Grass/brush
TS/GR	Tall sage/brush
TS/MB	Tall sage/mountain brush
M	Mahogany
WA	Bogs/ponds/lakes
WM	Wet meadows
R	Rock, talus, barren

Appendix C. Known or suspected goshawk nesting areas not included in habitat analysis. Given is the site number, location, year active and status indicating why it was not included.

Nest Site #	Location	Year Active	Status
D1-01	Divide Creek	90	no known nest; sighting only
D1-05	East Rattlesnake	83	no known nest; historical
D1-07	Pete Creek		stick nest found 85; no active nests or sign found 1993 survey
D3-03	Road 724	85-GGO*	nest stand completely fallen down 1991
D3-05	Anderson Mill	81	nest stand fallen apart; canopy cover < 25% 1991
D3-08	Porcupine	94,95	nest found 1995
D3-09	Hatchery Butte	95	nest found 1995
D4-02	Rocky Canyon	86-93	aspen stands; excluded on basis of habitat (non-conifer)
D4-03	Water Canyon	84	no nest known; historical
D4-05	Marlow	91	nest failed; no birds found 92-95; Level C surveys only
D4-06	Farnes Mt	91	not monitored due to time constraints
D4-07	Van Point	91	reported nest; never checked or monitored due to remote location
D5-02	Dry Creek II	85	no active nests found; not monitored consistently
D5-04	Bustle Creek	90	no known nest; recent surveys for ski hill EIS found no goshawks
D5-06	Canyon Creek	86	no known nest; historical
D5-08	Kirkham Hollow	88	birds reported; no nest found, unit clearcut where birds seen
D5-12	Dude Creek	94	nest found 1994
private	Rammell Hollow	94	nest found 1994
private	Milk Creek	94	nest found 1994

* GGO stands for Great Gray Owl

APPENDIX D. Correlations of spring weather variables on the TNF, 1989-1994. Key to terms: temp=temperature (C); precip=precipitation (cm), square root-transformed; snow depth= depth (cm), square-root transformed; SWE= snow water equivalents (%), arcsine transformed.

Variable	Correlated Variable	Correlation Coeeficient
March temp	April temperature	0.877
March temp	March/April temp	0.973
March temp	April/May temp	0.871
March temp	April/May precip	-0.788
April temp	March/April temp	0.964
April temp	April/May temp	0.893
April temp	May precip	-0.846
April temp	April/May precip	-0.835
May temp	April/May temp	0.784
May temp	April/May precip	-0.767
March/April temp	April/May temp	0.918
March/April temp	May precip	-0.810
March/April temp	April/May precip	-0.844
April/May temp	May precip	-0.959
April/May temp	April/May precip	-0.952
April precip	April/May precip	0.830
May precip	March/April precip	0.773
May precip	April/May precip	0.924
March SWE	March snow depth	0.863

APPENDIX E. Master list of goshawk nest trees found at study territories, Targhee NF, 1980-1994. Page 1.

	Nest ID	Year Found	Year Active	Tree Lost	Nest Tree Species	Other Raptor Species	Year Used by Other Species	#Tree-Year Checks 1989-1994
1	D1-02-1	1991	1991	x	SP-gone			
2	D1-02-2	1992	1992		SP	GGOW	93	2
3	D1-02-3	1989			DF			5
4	D1-03-1	1984	1992		DF			6
5	D1-04-1	1983	1985	x	DF-cut			
6	D1-04-2	1990	1990,91		DF			4
7	D1-04-3	1993	1993		DF			1
8	D1-04-4	1994	1994		DF			
9	D1-06A-1	1985	1992,94		DF			6
10	D1-06A-2	1990	1993		DF	LEOW, GGOW	91,94	4
11	D1-06A-3	1990			DF	GGOW	92,93	4
12	D1-06A-4	1990			DF			4
13	D1-06B-1	1990	1990		DF			4
14	D1-06B-2	1991	1991		DF			3
15	D1-06B-3	1991			DF			3
16	D1-08A-1	1990			DF			4
17	D1-08A-2	1992	1992		DF			2
18	D1-08A-3	1990		x	DF-gone			2
19	D1-08A-4	1993	1993		DF			1
20	D1-08A-5	1994	1994		DF			
21	D1-09-1	1983	83,89	x	DF-died	GGOW	90,92,93,94	6
22	D1-10-1	1988	1988		DF	GGOW	1990	6
23	D1-10-2	1989			DF	GGOW	91,92,93,94	4
24	D1-10-3	1991	1991		DF			3
25	D1-10-4	1991	92,95		DF			3
26	D1-10-5	1994	1994		DF			
27	D1-11-1	1989	1989,91		DF	GGOW	92,93	5
28	D1-11-2	1990	1990	x	DF-cut			
29	D1-11-3	1989		x	DF-cut			1
30	D1-11-4	1992			DF			2
31	D1-12-1	1993	1993		DF			1
32	D1-12-2a	1993			DF			1
33	D1-12-2b	1993			DF			1
34	D1-12-3	1993			DF			1
35	D1-12-4	1993			DF			1
36	D1-13-1	1993	1993		DF			1
37	D1-13-2	1993			DF	GGOW	93	1
38	D2-01-1	1989	1989		DF	GGOW	90	5
39	D2-01-2	1989			DF	GGOW	92	5
40	D2-01-3	1992	1992		DF			2
41	D2-01-4	1992			DF			1
42	D2-02-1	1988	1993		DF	GGOW	90,91	6
43	D2-02-2	1992	1992		DF	GGOW	94	2
44	D2-02-3	1992			DF	GGOW	92	2
45	D2-03-1	1990	1990		DF			4
46	D2-03-2	1992			DF			2

	Nest ID	Year Found	Year Active	Tree Lost	Nest Tree Species	Other Raptor Species	Year Used by Other Species	#Tree-Year Checks 1989-1994
47	D2-04-1	1990	1990		AS			4
48	D2-04-2	1992	1992		DF			2
49	D2-04-3	1992	1994		DF			2
50	D2-04-4	1992			DF			2
51	D2-04-5	1992			DF			2
52	D2-05-1	1991	91,92		LP			3
53	D2-06-1	1992	1992		LP	GHOW	94	2
54	D2-07-1	1992	1992		LP	COHA	90	2
55	D3-01-1	1990	1990		LP			4
56	D3-01-2	1991	1991		LP			3
57	D3-02-1	1981			LP	GGOW	81	
58	D3-04-1	1985	1985	x	LP-gone			
59	D3-06-1	1989	1989		DF			5
60	D3-07-1	1989	1989		DF			4
61	D4-01-1	1986	86,89,91		LP			5
62	D4-01-2	1992	1992		LP			1
63	D4-04-1	1985			DF			5
64	D4-04-2	1990	1991		DF			5
65	D4-04-3	1990			DF			5
66	D4-04-4	1992	1993		DF			1
67	D5-01-1	1980	1980	x	DF-cut			
68	D5-01-2	1981	1981	x	DF-gone			
69	D5-03-1	1990			DF	GGOW	91,92,93,94	4
70	D5-03-2	1992	1992		LP			2
71	D5-03-3	1993	1993		LP-snag			1
72	D5-05-1	1981	1981		DF			5
73	D5-05-2	1982	1982	x	DF-cut			
74	D5-05-3	1986	1986		DF			5
75	D5-07-1	1989	1989		DF	GGOW		5
76	D5-07-2	1991	1991		DF	GGOW	93	3
77	D5-07-3	1991	1992		DF	GGOW	91	3
78	D5-07-4	1993			DF			1
79	D5-09-1	1990	1990		DF			4
80	D5-09-2	1991	1991		DF			3
81	D5-09-3	1992	1992		DF			2
82	D5-09-4	1993	1993		DF			2
83	D5-09-5	1994	1994		DF			
84	D5-10-1	1991	1991,94		DF			3
85	D5-10-2	1992	1992		DF			2
86	D5-10-3	1993	1993		DF			1
87	D5-11-1	1992	1992		DF-snag			2
88	D5-11-2	1993	1993		DF			1
89	D5-11-3	1992	1994		DF	GGOW	92	2
	Total							229

Appendix F. Monitoring results for goshawk study territories 1989-1994, Targhee NF. Shown for each year are the number of young produced or survey level and total territory year-checks. Shaded cells indicate first year territory was discovered which was not counted as a monitored year.

Territory ID	1990	1991	1992	1993	1994	#Territory-Year Checks
	Monitoring Year Results*					
D1-02	2	3	2	b	c	5
D1-03	c	c	3	c	c	5
D1-04	2	0	c	1	3	5
D1-06	3	2	4	0	3	5
D1-08	c	a	2	2	3	4
D1-09	c	c	c	a	c	5
D1-10	c	2	0	a	2	5
D1-11	2	2	2	a	c	5
D1-12				1	b	1
D1-13				2	b	1
D2-01	b	c	2	b	b	5
D2-02	c	c	2	2	b	5
D2-03	3	o	a	c	b	4
D2-04	3	c	1	o	2	4
D2-05		1	1	a	b	3
D2-06			2	a	c	2
D2-07			2	a	c	2
D3-01	1	c	0	a	b	4
D3-02		c	a	c		3
D3-04		c	a	c	b	4
D3-06	c	c	c	c	b	5
D3-07	c	c	c	c	b	5
D4-01	c	0	2	b	a	5
D4-04	c	2	2	2	c	5
D5-01		b	a	b		3
D5-03		2	3	1	c	4
D5-05	b	b	c	c	c	5
D5-07	2	2	3	a	c	5
D5-09	2	2	3	1	3	4
D5-10		1	1	1	2	3
D5-11			4	3	3	2
Total territories monitored:	15	24	26	29	29	123
Total occupied territories	5	11	17	10	8	51
Total not occupied:	10	13	9	19	21	72
Number Level a surveys:	0	1	4	8	1	14
Number Level b surveys:	2	2	0	4	10	18
Number Level c surveys:	8	10	5	7	10	40

*Survey level key: a 1.6 radius km area checked b .8 km radius area checked , c nest stand checked only.

Appendix G . List of goshawk prey species and estimated weights used to calculate biomass.

COMMON NAME	SCIENTIFIC NAME	Weight (g)
BIRDS		
Duckling, sp.		100
Cooper's Hawk	*Accipiter cooperii*	437
Blue Grouse	*Dendrogapus obscurus*	1040
Ruffed Grouse	*Bonasa umbellus*	576
Grouse, sp.		808
Boreal Owl	*Aegolius funereus*	346
Long-eared Owl	*Asio otus*	262
Red-naped Sapsucker	*Sphyrapicus nuchalis*	49
Williamson's Sapsucker	*Sphyrapicus thyroideus*	48
Nothern Flicker	*Colaptes auratus*	142
Woodpecker, sp.		50
Gray Jay	*Perisoreus canadensis*	71
Steller's Jay	*Cyanocitta stelleri*	106
Clark's Nutcracker	*Nucifraga columbiana*	135
Common Raven	*Corvus corax*	876
Townsend's Solitaire	*Myadestes townsendi*	34
American Robin	*Turdus migratorius*	79
Bird (medium), unidentifed		100
MAMMALS		
Nuttall's Cottontail	*Sylvilagus nuttallii*	500
Snowshoe Hare	*Lepus americanus*	1600
Yellow-pine Chipmunk	*Tamias amoenus*	46
Marmot	*Marmota flaviventris*	1808
Unita Ground squirrel	*Spermophilus armatus*	245
Red Squirrel	*Tamiasciurus hudsonicus*	195
Northern Flying Squirrel	*Glaucomys sabrinus*	142
Pocket Gopher	*Thomomys talpoides*	128
Vole,sp.	*Microtus, sp.*	35
Small rodent, unidentified		40
Long-tailed Weasel	*Mustela frenata*	178
Medium mammal, unidentified		225

Appendix H. List of nest trees used in habitat analysis showing year occupied and tree species. ID number refers to district (D 1 to 5)-territory number-nest number on the Targhee NF. Key for tree species: SP Englemann Spruce, DF Douglas Fir, LP Lodgepole Pine, AS Aspen.

	ID#	Year Occupied	Tree Species	Level 1 Analysis	Level 2 Analysis	Used for Comparison of DF and LP nests	Number of Young
1	D1-02-3	1992	SP	x	x	x	2
2	D1-03-1	1992	DF	x	x	x	3
3	D1-04-2	90,91	DF	x	x		2,0
4	D1-04-3	1993	DF	x	x	x	1
5	D1-06A-1	92,94	DF	x	x	x	4,3
6	D1-06A-2	1993	DF	x			0
7	D1-06B-1	90,95	DF	x			3,0
8	D1-06B-2	1991	DF	x	x		2
9	D1-08A-2	1992	DF	x	x	x	2
10	D1-08A-4	1993	DF	x	x		2
11	D1-09-1	83,89	DF	x	x	x	?,3
12	D1-10-3	1991	DF	x	x	x	2
13	D1-10-4	1992	DF	x	x		0
14	D1-11-1	89,91	DF	x	x	x	3,2
15	D1-11-2	1990	DF	x	x		2
16	D1-12-1	1993	DF	x	x	x	1
17	D1-13-1	1993	DF	x	x	x	2
18	D2-01-1	1989	DF	x	x	x	1
19	D2-01-3	1992	DF	x	x		2
20	D2-02-1	1993	DF	x	x	x	2
21	D2-02-2	1992	DF	x	x		2
22	D2-03-1	1990	DF	x	x	x	3
23	D2-04-1	1990	AS	x			3
24	D2-04-2	1992	DF	x	x	x	1
25	D2-05-1	91,92	LP	x	x	x	1,1
26	D2-06-1	1992	LP	x	x	x	2
27	D2-07-1	1992	LP	x	x	x	2
28	D3-01-1	1990	LP	x	x	x	1
29	D3-01-2	1992	LP	x	x		0
30	D3-06-1	1989	DF	x	x	x	3
31	D3-07-1	1989	DF	x	x	x	1
32	D4-01-1	89,91	LP	x	x	x	0,0
33	D4-01-2	1992	LP	x	x		2
34	D4-04-2	89,91	DF	x	x	x	?,2
35	D4-04-4	93,95	DF	x			2,2
36	D5-03-2	1992	LP	x	x		3
37	D5-03-3	1993	LP	x	x	x	1
38	D5-07-1	1990	DF	x	x		2
40	D5-07-2	1991	DF	x	x	x	2
39	D5-07-3	1992	DF	x	x		3
41	D5-09-1	1990	DF	x	x		2
42	D5-09-2	1991	DF	x			2
43	D5-09-3	1992	DF	x	x		3
44	D5-09-4	1993	DF	x	x	x	1
45	D5-10-1	91,94	DF	x	x		1,2
46	D5-10-2	1992	DF	x	x		1
47	D5-10-3	1993	DF	x	x	x	1
48	D5-11-1	1992	DF	x	x	x	4
49	D5-11-3	1993	DF	x	x		3
	Total number:			49	44	27	

Appendix I. Summary of nest area (Level 3) GIS analysis for goshawk territories.

SITE #	acres	Mature Forest	Young Forest	Seedling	Sage/ Shrub	Open Area
Current territories:						
D1-02	199	67%	0%	0%	33%	0%
D1-03	198	51%	0%	0%	49%	1%
D1-04	198	65%	0%	35%	1%	0%
D1-06	199	88%	0%	9%	3%	0%
D1-08	199	94%	0%	6%	0%	0%
D1-09	199	60%	0%	40%	0%	0%
D1-10	197	53%	0%	46%	1%	0%
D1-11	198	76%	0%	24%	0%	0%
D1-12	198	100%	0%	0%	0%	0%
D1-13	198	100%	0%	0%	0%	0%
D2-01	198	80%	3%	0%	0%	17%
D2-02	199	62%	3%	35%	0%	0%
D2-03	199	100%	0%	0%	0%	0%
D2-04	198	78%	0%	0%	6%	16%
D2-05	198	43%	13%	44%	0%	0%
D2-06	198	35%	4%	61%	0%	0%
D2-07	199	25%	35%	40%	0%	0%
D3-01	199	55%	6%	40%	0%	0%
D3-06	200	24%	15%	57%	0%	4%
D3-07	198	100%	0%	0%	0%	0%
D4-01	198	60%	5%	34%	1%	0%
D4-04	198	99%	0%	0%	0%	0%
D5-03	197	80%	1%	13%	5%	2%
D5-07	199	49%	7%	44%	0%	0%
D5-09	200	65%	1%	4%	11%	20%
D5-10	199	71%	0%	0%	21%	8%
D5-11	199	64%	0%	0%	36%	0%
Historical territories:						
D3-02	199	44%	0%	56%	0%	0%
D3-04	198	24%	0%	76%	0%	0%
D5-01	196	44%	2%	54%	0%	0%
D5-05	198	38%	10%	35%	6%	11%

Appendix J Summary of post-fledgling family area (Level 4) GIS analysis for goshawk territories.

SITE #	acres	Mature Forest	Young Forest	Seedling	Sage/ Shrub	Open Area
Current territories:						
D1-02	400	73%	0%	2%	25%	0%
D1-03	390	54%	0%	0%	31%	15%
D1-04	394	71%	0%	14%	4%	11%
D1-06	400	60%	0%	31%	9%	0%
D1-08	400	66%	0%	34%	0%	0%
D1-09	398	62%	0%	32%	2%	4%
D1-10	402	48%	0%	47%	4%	2%
D1-11	398	92%	0%	7%	1%	0%
D1-12	399	99%	0%	0%	1%	0%
D1-13	400	86%	0%	13%	1%	0%
D2-01	400	72%	12%	0%	7%	9%
D2-02	400	59%	13%	27%	0%	0%
D2-03	398	99%	0%	0%	1%	0%
D2-04	401	55%	0%	0%	1%	43%
D2-05	397	21%	17%	62%	0%	0%
D2-06	399	57%	24%	20%	0%	0%
D2-07	398	16%	21%	63%	0%	0%
D3-01	397	45%	29%	25%	0%	0%
D3-06	397	69%	23%	9%	0%	0%
D3-07	399	100%	0%	0%	0%	0%
D4-01	401	56%	7%	23%	13%	0%
D4-04	400	89%	2%	0%	8%	1%
D5-03	380	71%	4%	21%	4%	1%
D5-07	381	70%	4%	24%	3%	0%
D5-09	399	61%	8%	4%	13%	14%
D5-10	397	55%	0%	0%	34%	11%
D5-11	376	66%	1%	0%	33%	0%
Historical territories:						
D3-02	397	46%	0%	51%	2%	1%
D3-04	398	45%	4%	49%	0%	2%
D5-01	401	58%	0%	35%	4%	3%
D5-05	399	33%	11%	28%	11%	18%

Appendix K. Summary of foraging area (Level 5) GIS analysis for goshawk territories.

SITE #	acres	Mature Forest	Young Forest	Seedling	Sage/ Shrub	Open Area
Current territories:						
D1-02	5394	55%	0%	4%	37%	4%
D1-03	4493	54%	0%	0%	45%	2%
D1-04	4848	54%	1%	9%	25%	12%
D1-06	5605	43%	1%	15%	41%	1%
D1-08	5505	58%	0%	24%	14%	4%
D1-09	5930	50%	0%	28%	10%	13%
D1-10	5754	55%	0%	33%	9%	4%
D1-11	5968	80%	0%	15%	4%	1%
D1-12	5034	81%	1%	13%	4%	0%
D1-13	5969	72%	1%	14%	8%	5%
D2-01	5938	74%	11%	4%	9%	3%
D2-02	5971	62%	12%	16%	6%	3%
D2-03	4137	84%	2%	8%	6%	0%
D2-04	3071	56%	10%	0%	28%	6%
D2-05	5967	46%	10%	41%	1%	2%
D2-06	5612	58%	7%	32%	1%	1%
D2-07	5969	34%	38%	27%	0%	0%
D3-01	5968	58%	3%	40%	0%	0%
D3-06	5576	67%	1%	30%	0%	2%
D3-07	5970	87%	1%	10%	1%	2%
D4-01	5970	67%	5%	16%	12%	0%
D4-04	5966	65%	8%	1%	18%	9%
D5-03	4088	60%	3%	30%	3%	3%
D5-07	4673	66%	4%	12%	16%	2%
D5-09	3240	59%	8%	20%	13%	1%
D5-10	5310	49%	0%	0%	38%	13%
D5-11	3752	67%	1%	1%	29%	3%
Historical territories:						
D3-02	5969	41%	1%	52%	3%	3%
D3-04	5967	50%	1%	46%	2%	2%
D5-01	5266	51%	1%	4%	4%	5%
D5-05	3205	68%	4%	15%	12%	1%

APPENDIX L. Comparison of productivity of active nests in DF/mixed conifer and LP habitat, 1989-1994. Zero's indicate nest failures. Blanks indicate years where no evidence of nesting was documented. Difference between mean productivity of DF and LP territories significant (p=0.015) (MRPP analysis).

	Years Monitored							Total		Mean #
Territory ID#	1989	1990	1991	1992	1993	1994	1995	# Young Produced	#Years Active	Young per Territory
DF/Mixed Conifer Territories:										
D1-02	2	2	3	2				9	4	2.3
D1-03				3				3	1	3.0
D1-04		2	0		1	3		6	4	1.5
D1-06		3	2	4	0	3	0	12	6	2.0
D1-08				2	2	3		7	3	2.3
D1-09	3							3	1	3.0
D1-10			2	0		2	0	4	4	1.0
D1-11	3	2	2	2				9	4	2.3
D1-12					1		2	3	2	1.5
D1-13					2		0	2	2	1.0
D2-01	1			2				3	2	1.5
D2-02				2	2			4	2	2.0
D2-03		3						3	1	3.0
D2-04		3		1		2		6	3	2.0
D3-06	3							3	1	3.0
D4-04			2	2	2		2	8	4	2.0
D5-03			2	3	1		1	7	4	1.8
D5-07	1	2	2	3				8	4	2.0
D5-09		2	2	3	1	3	0	11	6	1.8
D5-10			1	1	1	2	3	8	5	1.6
D5-11				4	3	3	3	13	4	3.3
# young	13	19	18	34	16	21	11	132	mean:	2.08
# active nests	6	8	10	15	11	8	9		SD:	0.66
#young/nest	2.17	2.38	1.80	2.27	1.45	2.63	1.22			n=21
LP TERRITORIES:										
D2-05			1	1				2	2	1.0
D2-06				2				2	1	2.0
D2-07				2				2	1	2.0
D3-01		1		0				1	2	0.5
D3-07	1							1	1	1.0
D4-01	0		0	2			2	4	4	1.0
# young	1	1	1	7	0	0	2	12	mean:	1.25
# active nests	2	1	2	5			1		SD:	0.61
#young/nest	0.50	1.00	0.50	1.40			2.00			n=6

APPENDIX M.. Proportion of mature forest cover at three spatial scales pre and post-harvesting at goshawk territories discovered before tree removal. Percent mature forest cover in the pre-harvest period was estimated by assuming all harvested units identified in the GIS database were formerly mature forest. Differences in mature forest cover pre and post-harvest were significant within all three analysis areas (MRPP).

		Nesting Area (81 ha)			PFA (162 ha)			Foraging Area (2428 ha)		
		Pre-harvest	Post-Harvest		Pre-harvest	Post-Harvest		Pre-harvest	Post-Harvest	
	Site#	% mature	% mature	% cut	% mature	% mature	% cut	% mature	% mature	% cut
1	D1-04	100	65	35	90	69	21	63	54	9
2	D1-09	100	60	40	96	61	35	78	50	28
3	D1-10	99	53	46	96	50	47	88	55	33
4	D1-11	100	76	24	99	86	13	95	80	15
5	D2-02	97	62	35	90	60	30	76	62	14
6	D4-01	94	60	34	84	57	27	83	67	16
7	D5-01	77	44	33	82	58	24	85	51	35
8	D5-05	73	38	35	61	33	28	83	68	15
9	D5-07	93	49	44	93	63	31	75	66	9
10	D5-09	69	65	4	66	62	4	79	59	20
	mean	90	57	33	86	60	26	80	61	19
	std dev.	12	11	12	13	13	12	9	10	9
MRPP results:		(p=0.001)			(p=0.001)			(P=0.0004)		

Appendix N. Comparison of mature forest cover at high and low occupancy post-harvest territories. Low occupancy was defined as territories that had 50% or lower occupancy rates based on a minimum of three years monitoring data. The difference between these groups was significant (p=0.002, MRPP).

	Occupancy Rate	# Nests	Percent of Mature Forest Cover		
			NA	PFA	FA
High occupancy territories (post-harvest)					
D1-04	0.67	3	65%	71%	54%
D1-06	1.00	7	88%	60%	43%
D1-08	0.60	5	94%	60%	58%
D1-10	0.80	5	53%	48%	55%
D1-11	0.67	2	76%	92%	80%
D4-01	0.60	2	60%	56%	67%
D5-03	1.00	3	80%	71%	60%
D5-09	1.00	5	65%	61%	59%
mean	79%	4.0	73%	65%	59%
SD	18%	1.8	14%	13%	11%
Low occupancy territories (post-harvest)					
D1-09	0.33	1	60%	62%	50%
D2-02	0.33	3	62%	59%	62%
D2-05	0.50	1	43%	21%	46%
D3-01	0.40	1	55%	45%	58%
D5-01	0.00	0	44%	58%	51%
D5-05	0.00	2	38%	33%	68%
D5-07	0.33	4	49%	70%	66%
mean	27%	1.7	50%	50%	57%
SD	19%	1.4	9%	18%	9%